SCHEDULING WITH ALTERNATIVES MACHINE USING FUZZY INFERENCE SYSTEM AND GENETICA LGORITHM

DR-SHAHRUL KAMARUDDIN

UNIVERSITI SAINS MALAYSIA
KAMPUS KEJURUTERAAN
2008

UNIVERSITI SAINS MALAYSIA

Laporan Akhir Projek Penyelidikan Jangka Pendek

Scheduling with Alternatives Machine using Fuzzy Inference System and Genetic Algorithm

by

Dr. Shahrul Kamaruddin

Mohzani Mokhtar

Dr. Khairanum Subari

Dr. Zalinda Othman

UNIVERSITI SAINS MALAYSIA

PEJABAT PENGURUSAN & KREATIVITI PENYELIDIKAN
RESEARCH CREATIVITY AND MANAGEMENT OFFICE [RCMO]

LAPORAN AKHIR PROJEK PENYELIDIKAN JANGKA *PENDEK*
FINAL REPORT OF SHORT TERM RESEARCH PROJECTS

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1) **Nama Ketua Penyelidik** :
Name of Research Leader :

Ketua Penyelidik *Research Leader*	PTJ *School/Centre*
DR. SHAHRUL KAMARUDDIN	**MECHANICAL ENGINEERING**

Nama Penyelidik Bersama
(Jika berkaitan) :
Name/s of Co-Researcher/s
(if applicable)

Penyelidik Bersama *Co-Researcher*	PTJ *School/Centre*
MR. MOHZANI MOKTHAR	**MECHANICAL ENGINEERING**
DR. KHAIRANUM SUBARI	**TRANSFER TO MSI, UNIKL, KULIM**
DR. ZALINDA OTHMAN	**TRANSFER TO UKM, BANGI**

2) **Tajuk Projek** :
Title of Project:

SCHEDULING WITH ALTERNATIVES MACHINE USING FUZYY INFERENCE SYSTEM AND GENETIC ALGORTIHM

3) **Abstrak untuk penyelidikan anda**

(Perlu disediakan di antara 100 – 200 perkataan di dalam **Bahasa Malaysia dan Bahasa Inggeris.** Ini kemudiannya akan dimuatkan ke dalam Laporan Tahunan Bahagian Penyelidikan & Inovasi sebagai satu cara untuk menyampaikan dapatan projek tuan/puan kepada pihak Universiti & luar).

Abstract of Research

(Must be prepared in 100 – 200 words in Bahasa Malaysia as well as in English. This abstract will later be included in the Annual Report of the Research and Innovation Section as a means of presenting the project findings of the researcher/s to the university and the outside community)

ABSTRACT ENGLISH VERSION

As the manufacturing activities in today's industries are getting more and more complex, it is required for the manufacturing company to have a good shop floor production scheduling to plan and schedule their production orders. An accurate scheduling is essential to any manufacturing company in order to be competitive in the global market. This research is an empirical study about the assembly process of various manufacturing industries in Malaysia in order to investigate the impact of variety of orders and different number of workers on the performance of their production scheduling. Two methods were selected in the empirical study that is forward scheduling and backward scheduling. In addition, two types of shop floors which are job shop and cellular layout were used as a benchmark to analyse the impact of the methods listed. Consequently, the performance of forward scheduling and backward scheduling in both job shop and cellular layout were compared using simulation method, and the results were analysed by using Analysis of Variance (ANOVA). Through the analysis, the best scheduling approach and layout to be used by manufacturing firm in order to achieve the make-to-order (MTO) production and inventory strategy were reported.

ABSTRAK BAHASA MALAYSIA

Industri pengeluaran kini telah berkembang pesat dan aktiviti pengeluarannya semakin kompleks, dengan itu syarikat pengeluar memerlukan jadual lantai pengeluaran (shop floor) yang terbaik untuk merancang permintaan pengeluaran (product). Ketepatan penjadualan in amat penting untuk syarikat pengeluar supaya boleh bersaing diperingkat global. Penyelidikan ini merupakan penyiasatan awal mengenai proses penghasilan produk dipelbagai industri pengeluaran di Malaysia untuk mengkaji kesan di antara kepelbagaian tempahan dan perbezaan bilangan pekerja pada prestasi penjadualan pengeluaran. Dua kaedah dipilih untuk penyiasatan awal ini iaitu penjadualan kehadapan (forward) dan penjadualan kebelakang (backward). Sementara itu, dua jenis lantai pengeluaran (shop floor) iaitu "job shop" dan "cellular layout" digunakan sebagai penanda aras untuk menganalisa kesan yang telah dinyatakan di atas. Prestasi untuk penjadualan kehadapan (forward) dan penjadualan kebelakang (backward) pada lantai pengeluaran (shop floor) "job shop" dan "cellular layout" dibandingkan dengan menggunakan kaedah simulasi dan keputusan akan dianalisa dengan menggunakan "Analysis of Variance (ANOVA)". Berdasarkan analisis tersebut, pendekatan penjadualan dan susun atur yang terbaik dipilih untuk mencapai pengeluaran make-to-order (MTO) yang berkesan.

4) Sila sediakan Laporan teknikal lengkap yang menerangkan keseluruhan projek ini.
[Sila gunakan kertas berasingan]
Kindly prepare a comprehensive technical report explaining the project (Prepare report separately as attachment)

Senaraikan Kata Kunci yang boleh menggambarkan penyelidikan anda :
List a glosssary that explains or reflects your research:

Bahasa Malaysia	Bahasa Inggeris
Shop floor	Lantai Pengeluaran
Scheduling	Penjadualan
Discrete Simulation	Simulasi Berasingan

5) **Output Dan Faedah Projek**
Output and Benefits of Project

(a) * Penerbitan *(termasuk laporan/kertas seminar)*
Publications (including reports/seminar papers)
(Sila nyatakan jenis, tajuk, pengarang, tahun terbitan dan di mana telah diterbit/dibentangkan).
(Kindly state each type, title, author/editor, publication year and journal/s containing publication)

The main output of this research is the framework of the shop floor scheduling approaches from the practical point of view. The framework can be used in analysing other shop floor environment especially for deriving a robust schedule in day to day running of the shop floor. As a future work the developed framework can be used in capturing and solving the more complicated shop floor environment by considering the dynamic factors such as changes of priority of orders, machine breakdowns and etc.

Publications:

1. A Comparative Study Of Flexible Assembly Line And Mixed Model Assembly Line, Fawad Ahmed, Zalinda Othman, Khairanum Subari, Arif Suhail, Proceedings of the 4th Mechanical Engineering Research Colloquium (MERC 2005/I) School of Mechanical Engineering, USM, Penang, Malaysia, 27-29 January 2005
2. A Preliminary Study On Layout Design Based On Make To Order Environment, Noor Ain Ibrahim, Zalinda Othman and Khairanum Subari, Proceedings of the 4th Mechanical Engineering Research Colloquium (MERC 2005/I) School of Mechanical Engineering, USM, Penang, Malaysia, 27-29 January 2005
3. Ahmad Shamsul Osman, Shahrul Kamaruddin, Rosnah Idrus And Zalinda Othman, Development Of Dynamic Gantt Chart From The Production Scheduling Prespective, International Conference on Science & Technology: International Conference on Science & Technology: Application in Industry & Education 8-9 December 2006, Universiti Teknologi MARA, Pulau Pinang, Malaysia
4. C. H. Soh and S. Kamaruddin, Application Of Artificial Intelligence (Ai) In Layout Design And Planning, International Conference on Science & Technology: International Conference on Science & Technology: Application in Industry & Education 8-9 December 2006, Universiti Teknologi MARA, Pulau Pinang, Malaysia
5. Tan Yean Ching and Shahrul Kamaruddin, Application Of Simulation In Layout Design And Planning, International Conference on Science & Technology: International Conference on Science & Technology: Application in Industry & Education 8-9 December 2006, Universiti Teknologi MARA, Pulau Pinang, Malaysia

(b) **Faedah-Faedah Lain Seperti Perkembangan Produk, Prospek Komersialisasi Dan Pendaftaran Paten atau impak kepada dasar dan masyakarat.**
Other benefits such as product development, product commercialisation/patent registration or impact on source and society

Industrial collaboration was achieved between School of Mechanical Engineering and Automotive Lighting (M) Sdn. Bhd. Penang. The company has agreed upon to provide all the required data for verifying and validating the framework and algorithms. IN addition the collaboration has open various opportunities to the students to experience a real working environment by carrying out project based on the company needs and problems.

* Sila berikan salinan
* *Kindly provide copies*

(c) **Latihan Gunatenaga Manusia**
Training in Human Resources

i) Pelajar Siswazah :
Postgraduate students:
(perincikan nama, ijazah dan status)
(Provide names, degrees and status)

1. Fawad Ahmed, MSc, Correction After Viva
2. Noor Ain Ibrahim, MSc. On going

ii) Pelajar Prasiswazah :
Undergraduate students:
(Nyatakan bilangan)
(Provide number)

1. Tan Su Ying, Production Yield Improvement Uisng Six Sigma Methodology (DMAIC): A Case Study
2. Koo Khim Khim, Productivity Improvement on Relieving the Bottleneck Operation In An Assembly Line: A Case Study At Automotive Lighting (M) Sdn. Bhd.
3. Faharuddin Ngatami, Analysis of the Effect of Dynamic Issues in Scheduling of Flow Shop Environment
4. Norliana Ahmad, Analysis of the Effect of Dynamic Issues in Scheduling of Job Shop Environment

iii) Lain-Lain :
Others:

None

6. **Peralatan Yang Telah Dibeli :**
Equipment that has been purchased:

A Note Book Computer (Toshiba)

KOMEN JAWATANKUASA PENYELIDIKAN PUSAT PENGAJIAN
Comments of the Research Committees of Schools/Centres

The research work has significant output relevant to industries and academic field.

TANDATANGAN PENGERUSI
JAWATANKUASA PENYELIDIKAN PUSAT PENGAJIAN
Signature of Chairman
[Research Committee of School/Centre]

26/8/07
TARIKH
Date

Attachment 1: Technical Report

TECHNICAL REPORT

Overview

Scheduling is defined as the allocation of resources over time to accomplish specific tasks. It can be considered as an integral part of the shop floor production planning process. Scheduling in production environment is being carried out with multiple objectives in practice. Production scheduling is a process which plan the production based on customer orders in order to determine the best sequence of orders to be produce to fulfill customer demand. For most manufacturing firms, production scheduling is a very difficult task. Production layout must perform well on several competing objectives. For example, a make-to-order manufacturing firm must control its inventory level but at the same time must also ship its customer's orders on time.

The aim and objective of this research is to investigate the impact of variety of orders and different number of workers on the performance of production scheduling approach using Witness simulation package. There have been many different types of scheduling approach available, but forward scheduling and backward scheduling are chosen in this research since only little attention is given to them under scheduling literature. The performance between these scheduling approaches will be compare in both job shop and cellular layout because these layouts are the popular layout used in today's manufacturing environment. The best scheduling approach and layout to be used by manufacturing firm in order to achieve the make-to-order (MTO) production and inventory strategy will be reported.

This report is organized as follows. In next section, a brief description of forward scheduling and backward scheduling approach and a review of the existing work that has led up to this research. This is followed by a clarification about the research methodology. Finally, the results and discussions on the implications of the methods on the shop floor environment analysed. In the final section, a conclusion is drawn from this research is discussed and some suggestions for future work are made to strengthen this research.

Introduction

Shop floor is a workplace consisting of the part of a factory housing the machines. In a factory, the productive work is done on the shop floor. There may have many different types of layout in the shop floor, namely flow shop, job shop, cellular layout, parallel layout, and etc. Nowadays, the comparison and analysis between the performance of job shop and cellular layout is being one of the popular research topics. Both layouts are also very common used in today's manufacturing environment. Canel et al. (2003) developed and compared the performance of two different layouts which is job shop and focused cellular manufacturing (FCM) by simulation. Their results show that the FCM layout scheme's major advantage is an improvement in batching delays before assemble, while the job shop scheme's major advantage is from better flexibility in part routing which provides better balance in machine utilizations. On the other hand, the relationship between processing time learning rate and flow time performance in both job shop and cellular layout are illustrated based on queuing theory by Kannan and Palocsay (1999). Models are developed that make it possible to estimate the learning rate required in a cellular layout in order for it to yield performance comparable to job shop. They used simulation to validate the models under dynamic conditions as opposed to the steady state conditions assumed by queuing theory. The result indicates that a cellular layout need only achieve a marginally higher learning rate than a job shop in order to perform at a comparable level. Future work for the authors include other shop factors such as material handling and variable batch sizes to provide more representative models of the shops.

Scheduling can be considered as an integral part of the production planning process. Planning and scheduling activities take place on many different levels, such as factory level, shop level, workstation level, and equipment level. Son and Wysk (2001) used a factory level planner and scheduler to show the possibility of performing planning and scheduling activities using the generated simulation model. Make span was the only performance measure used in their study. Because of planning and scheduling activities are extremely complicated, the parameters such as rescheduling point, planning or scheduling horizon, and performance measures need to be determined in order to make planning or scheduling more realistic.

Scheduling is further complicated by the dynamic environment of the shop floor in which the product orders may change over time. In such situations, the production sequences of the shops have to be changed each time the product order is changed. Holthaus (1997) characterised the dynamic job shop scheduling problem as follows; "in a manufacturing system which comprises M machine (workstations) jobs arrive continuously over time. Each job consists of a specified set of operations which have to be performed in a specified sequence on the machine. Schedules for processing the jobs on each of the M machines have to be found which are best solutions with respect to given flow time or due-date-based objectives". On the other hand, Yellig and Mackulak (1995) classified the current scheduling research into two categories, reactive real-time deterministic scheduling and proactive stochastic scheduling. Reactive scheduling methodologies focus on developing optimal schedules based on current shop floor status. Proactive stochastic scheduling is based on the premise that a good production policy should anticipate failures. Deterministic scheduling in a dynamic environment requires rescheduling to realign the schedule to actual production. This rescheduling degrades performance to customer promise dates. A reduction in throughput is suggested by authors to obtain the optimal level of performance to customer promise dates. The important to obtain a deterministic schedule was highlighted by Golenko-Ginzburg and Gonik (1997). The authors were concerned with a problem of scheduling a flexible manufacturing cell with random time operations. A deterministic schedule is obtained by them for feeding-in the resources which guarantees, with a chance constraint, that each order can meet its due date on time. Developing such a schedule will prevent the premature feeding-in of costly resources. The used of Evolutionary Algorithms (EA) in scheduling possess a significant potential for solving manufacturing control problems. Käschel et al. (2002) introduce an evolutionary search algorithm for shop floor scheduling and integrate the scheduler with a bidirectional plant data acquisition (PDA) system used for data collection as well as distribution of sequencing information. The authors discussed a quality improvement of evolutionary tools by separating the time-consuming scheduling procedure from the EA and distributing it throughout intelligent data terminals in their research.

Forward scheduling is a scheduling approach that established a schedule from an estimated start date to determine an appropriate completion date. Backward scheduling is the reverse of the forward scheduling approach and schedules are defined on a reverse time frame or backward time from the tasks completion date to determine its appropriate start date. The start time and completion time of the same order in forward scheduling is related to the completion time and start time respectively, of the same order in backward scheduling. Example of previos research where two simulated annealing heuristic using both forward and backward scheduling were presented by Ganesan et al. (2004) to address the problem of hierarchical minimization of completion time variance (CTV) and make span in a static job shop problem. Their results showed that the backward scheduling heuristic using simulated annealing algorithm performs better than the one using forward scheduling. The scope of their approached can be tested further by analyzing the performance on problems taken from real case using dispatching rules. On the other hand, Kawtummachai et al. (1997) applied the backward scheduling with the meta scheduling methods which are Genetic Algorithms (GA) and Simulated Annealing (SA), and then construct and test the scheduling algorithms by using a simulation method for an automated flow shop scheduling problem. The authors intended to minimize the total cost calculated through the production schedule of orders. The results of the simulation test have been compared to find the performance of their proposed method.

In production scheduling, it is important that not only the orders are not produced to late, it is also important that orders are not produced to early. Late orders may affect company reputations or breaking customer relations, while early orders which customers are not willing to accept may increase storage capacity. Thus, the principles of just-in-time (JIT) scheduling rules should be apply in this case. Ertay (1998) used SIMAN to model and simulates the JIT philosophy which applies to a company that is a sub-contractor of the automotive industry. After that, an economic analysis is performed using the simulation results. By the simulation experiments, the transfer lot size (container size) is decrease due to the reduction in lead time. Besides that, the variations in the lead times are become smaller due to the balanced of the machines operation times.

Simulation is widely used in almost all industry sectors. It is a commonly used tool to gain insight into the operational behaviour of manufacturing systems. Nowadays, there have been many simulation software languages available such as GPSS, SLAM, SIMAN, and WITNESS. According to Habchi and Berchet (2003), the most important reasons and advantages of simulation methodology for modeling manufacturing systems are:

- realistic models are possible, they are a practical approach to representing the important characteristics of a manufacturing system and may incorporate any complex interactions that exist between different variables;
- options may be considered without direct system experimentation and alternative designs can be easily evaluated, independently of the real system;
- a computer simulation models ability to directly address the performance measures typically used in a real system;
- non-existent systems may be modeled;
- visual output helps and assists the end-user in model development and validation; and
- no advanced mathematics is required.

Research methodology

The methodology that used to conduct this research is presented in this section as follow.

An Empirical Study

An empirical study has been carried out based on the assembly process of a radio cassette player manufacturer. In real environment, manufacturing industries always faced the problems of unexpected events such as order changes, machine breakdowns, product quality problems, operator absent, and etc. In order to react to such dynamic environments, a manufacturing company must select a suitable scheduling approach to schedule their day to day jobs. Therefore, a comparison and analysis between the performance of forward scheduling and backward scheduling on the shop floor production is carried out. The variety of orders and different number of workers were considered in a simulation model in order to study their impacts towards the performance of the scheduling approaches.

Forward Scheduling and Backward Scheduling Approach

In this research, different production orders need to be schedule in order to achieve on-time delivery and meet customer demand. The schedules of forward scheduling is constructed using weighted first come first served (WFCFS) priority scheduling rule. WFCFS rule is an integration of first come first served (FCFS) rule with total priority index. WFCFS means an order which is first receive by the manufacturer will be processed first, but if two or more orders having the same order date, an order with the highest total priority index will be processed first. The total priority index W is the sum of customer priority index and order quantity priority index. This is to ensure that the types of customer and size of order quantity have take into consideration when schedule the production orders. After that, backward scheduling is carried out by reverse the sequence of order given by forward scheduling. The sequential order of backward scheduling start from the last sequence order of forward scheduling and proceed backward toward the first sequence order of forward scheduling.

Simulation Study

Simulation is widely used in almost all industry sectors. It is a commonly used tool to gain insight into the operational behaviour of manufacturing systems. The computer simulation is used due to the advantages of lower cost, shorter time, greater flexibility and smaller risk if compared with direct real experimentation. In this research, WITNESS simulation package was used to build the simulation model. The objectives of simulation to be done in this research are:

i. To develop a discrete event simulation of job shop and cellular layout based on the assembly tasks of radio cassette player.
ii. To compare and analyze the performance of forward scheduling and backward scheduling in job shop and cellular layout against variety of orders and different number of workers.

Data Collection

In simulation development, data is required to build the simulation model. The data for modeling the simulation model was obtained from various manufacturing industries. There are total 49 tasks in the manufacturing assembly, each task with its own assembly time. Besides that, the bill of materials (BOM) for the products also need to be determined. Then only the simulation model of job shop and cellular layout can be design and develop according to the assembly tasks.

To test and compare the performance of forward scheduling and backward scheduling in job shop and cellular layout, three types of production orders were develop named as

i. Low volume – which contained 5 to 8 number of orders with order quantity equal to 6000 units.
ii. Medium volume – which contained 9 to 12 number of orders with order quantity equal to 8000 units.
iii. High volume – which contained 13 to 16 number of orders with order quantity equal to 10000 units.

These production orders from different customer are a monthly order which contains different order quantity, order date, and set-up time for each order. The due date of these production orders are 20 days.

Development of Simulation Model

Hand simulation is performed before attempting to build the model on WITNESS to ensure that the structure of the model is well planned and thought. A model is built on paper first and used to analyse the model when it is build on WITNESS later. 4 shops and 4 cells are developed in job shop and cellular layout, according to the assembly tasks of the production floor. Each cell contains a number of assembly workstation, and some workers are assigned to handle more than 1 workstation within each cell to balance the workload of worker. Job shop are not allowed to do so because it is only one workstation which contains a number of assembly tasks for each worker within each shop, and cannot be simply separated the assembly tasks to let the worker handle more than 1 workstation because the criteria of job shop have to follow. Therefore, the workload of worker and processing time of each workstation in cellular layout are more balanced than job shop. In order to compare the performance between job shop and cellular layout, the numbers of workers in both layouts are set to be the same. The example of conceptual model for job shop and cellular layout which contains 11 workers is shown in Figure 1 and Figure 2.

Several assumptions that have been made in building the simulation model are as listed below:

i. All the component parts of model were assumed to be available as and when required by the system.
ii. The cycle time and processing sequence of all different types of models was assumed to be same. Only the set-up time for each model is different.
iii. Utilise the available workstation rule, where when the workstation is available for work, it will continue to work until all the production orders is finished.
iv. The productions are assumed to be in ideal case, where no product quality problems occur.
v. Products travel times between workstation are assumed to be constant.
vi. The operator moving time between workstation in cellular layout are assumed to be constant.

To create a model in WITNESS, the first step is to decide which elements are included. After that, those elements have to be detailed with their individual characteristics, such as insert the cycle time and set-up time for each workstation.

Then the elements are linked with rules and action. For example, whether workstation are pushed to or pulled from another workstation. Then, labour element was attached to the workstation with detailed such as assign the labour to operate or set-up the workstation.

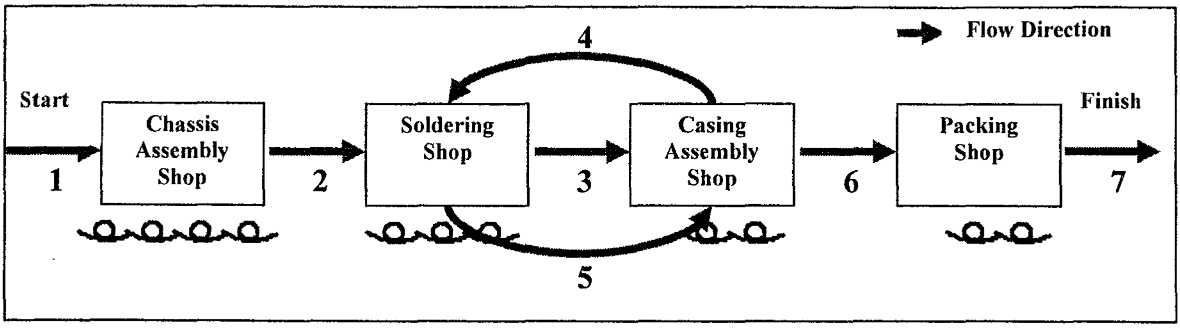

Figure 1: Conceptual model for job shop

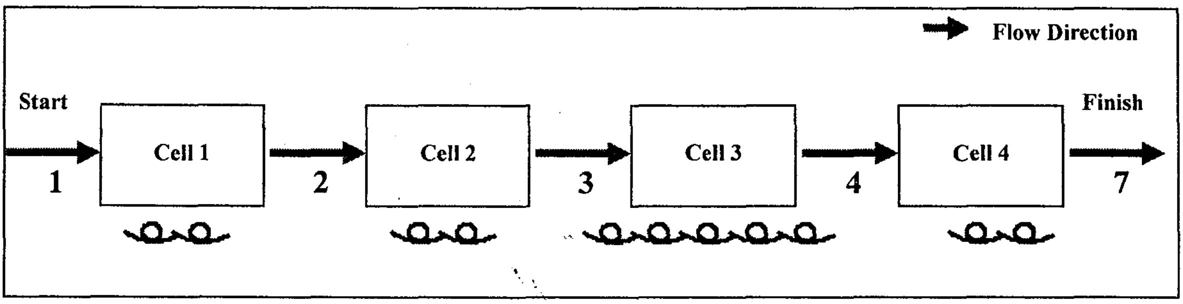

Figure 2: Conceptual model for cellular layout

3.6 Model verification and validation

After the simulation model is built, it will undergo the verification and validation process. To verify that the model building is right, the global process view of the simulation model is careful observed and compare with the model that is built by hand simulation. The label rules and detail of each element are checked to confirm the correctness of simulation model. Since there do not have any historic data to validate with in this research, the model was validated by comparison of the results it generated with mathematical calculation results.

Design of Experiment

Two experiments have been design and developed in this research in order to study the impact of variety of orders and different number of workers on the performance of forward scheduling and backward scheduling.

- ***Experiment on The Variety Of Orders***

In scheduling environment, production orders are always change from time to time. The purpose to run this experiment is to test the level of adaptation of the simulation model towards sudden increase or decrease number of orders and order quantity. It tested the flexibility of assembly process in accommodate the variety number of orders and order quantity in order to help manufacturing firm determine which production and inventory strategy to be used. Three different types of production orders which are low volume, medium volume and high volume as stated in previous section were analysed in the simulation model. To compare the performance of job shop and cellular layout, the number of workers is fixed at 11 workers.

- ***Experiment On The Different Number Of Workers***

In this experiment, three different numbers of workers which is 10 workers, 11 workers and 12 workers will be test on each of the simulation model. This is to study the impact of either increase or decrease the number of workers in production line towards dependent variables. For both job shop and cellular layout, the experiments were run on 11 workers model first. Then, 1 worker was added to soldering shop and cell 4 of job shop and cellular layout because it was a system bottleneck. After that, 1 worker was reduced from chassis assembly shop and cell 3 of job shop and cellular layout since it contains most number of workers. This experiment will be run on low volume (5 number of orders with 6000 quantity), medium volume (9 number of orders with 8000 quantity), and high volume (13 number of orders with 10000 quantity).

- ***Warm-up Period***

To alleviate the bias introduced by unrepresentative initial conditions, simulation runs typically include a warm-up period to achieve steady-state condition. In this research, starting conditions is used as an alternative of warm-up-period. The simulation model is assumed to starts from empty with no parts, work-in-progress or resources available.

- ***Dependent Variables***

The performance of scheduling approach will be evaluated on three dependent variables as follow:

i. Average throughput time, which is defined as time taken to produce one unit of product in the system. It is important as it relates to system efficiency. Average throughput time is expressed as

   Average throughput time = Flow Time / Total Output -------------------- ---- (1)

ii. Lateness, which is defined as the amount of time by which a job missed its due date. It is used to measure the system ability to deliver on time. If the value of lateness is positive, it can be consider as tardiness whereas if the value of lateness is negative, it can be consider as earliness. Lateness is expressed as

   Lateness = Total Completion Time - Due Date Time -------------------------- (2)

iii. Labour productivity, which is defined as the number of products being produced by a worker in unit time. It is a measurement on the productivity level of workers in the shop floor. Labour productivity is expressed as

   Labour Productivity = Total Output / (No. of Worker * Flow Time) -------- (3)

Results and Discussion

All results will be reported in mean values which obtained from 5 replication runs. To analyze the results, one-factor analysis of variance (ANOVA) with repeated measures was used. Two tests have been carried out in ANOVA. The first test is hypothesis test which have been carried out to examine whether all treatment means are random samples from a common normal population. The basic purpose of ANOVA is to test the following hypothesis:

H_0: There is no significant effect of treatment means on dependent variables.

H_1: There is significant effect of treatment means on dependent variables.

If the calculated F value greater than the critical value F, null hypothesis (H_0) will be reject and we accept alternative hypothesis (H_1). The second test, test for trend have been carried out to determine the form of relationship between independent variable and dependent variable using orthogonal polynomials.

Impact of Variety Of Orders On Scheduling Approach

Summary of ANOVA are shown in Table 1 where average throughput time for low volume in job shop using forward scheduling is used as an example. The rest of the calculated F values are as presented in Table 2.

Table 1: Summary of ANOVA on average throughput time for low volume in job shop using forward scheduling

Source of Variation	SS	df	MS	F
Between SS	0.00019657	4		
Within SS	0.00002391	15		
Treatment	0.00002131	3	0.00000710	32.78*
Residual (Error)	0.00000260	12	0.00000022	
Total	0.00022048	19		

$F_{0.95}(3,12) = 3.49$, $F_{0.99}(3,12) = 5.95$ *Significant at $\alpha = 0.01$

Table 2: The calculated F value for eexperiment on the variety of orders

Dependent Variable	Volume	Job Shop		Cellular Layout	
		Forward	Backward	Forward	Backward
Average Throughput Time	Low	32.78*	7.19*	28.53*	16.74*
	Medium	7.54*	5.03^{+}	7.88*	5.27^{+}
	High	8.90*	3.39^{+}	8.67*	3.83^{+}
Lateness	Low	35.21*	7.26*	28.86*	16.68*
	Medium	7.08*	4.78^{+}	7.73*	5.22^{+}
	High	7.94*	3.57^{+}	8.59*	3.87^{+}
Labour Productivity	Low	35.80*	7.24*	28.83*	16.83*
	Medium	7.05*	4.76^{+}	7.73*	5.22^{+}
	High	7.93*	3.57^{+}	8.55*	3.88^{+}

$F_{0.95}(3,12) = 3.49$, $F_{0.99}(3,12) = 5.95$
*Significant at $\alpha = 0.01$
$^{+}$Significant at $\alpha = 0.05$

From Table 2, it is indicated that all the calculated F value are greater than the critical F value at 99% level of significance except the dependent variables of medium and high volume for backward scheduling in both job shop and cellular layout. However, those calculated F value are still greater than the critical F value at 95% level of significance. Therefore, null hypothesis (H_0) is rejected and concluded that the effect of variety of orders for all three production volume on dependent variables are significant. Since the cycle time and processing sequence of all different types of model are assumed to be same in this research, thus it is only set-up time play a role in determining whether the effect will be significant or not. Set-up time is the time used to reset the workstation when each production order is changed. Thus, total set-up time used to reset the workstation will be increased when the number of orders is increased until alter the dependent variables and lead to the significant effect occur.

After that, test for trend is carried out to determine the response trend between independent variable and dependent variable using orthogonal polynomials. Summary of ANOVA with trend components are shown in Table 3 where throughput time for low volume in job shop using forward scheduling average is used as an example.

Table 3: Summary of ANOVA with trend components on average throughput time for low volume in job shop using forward scheduling

Source of Variation	SS	df	MS	F
Between SS	0.00019657	4		
Within SS	0.00002391	15		
Treatments	0.00002131	3	0.00000710	32.78
Linear	0.00002043	1	0.00002043	94.26*
Quadratic	0.00000000	1	0.00000000	0.00
Cubic	0.00000088	1	0.00000088	4.08
Residual	0.00000260	12	0.00000022	
Total	0.00026571	19		

$F_{0.95}(1,12) = 4.75$, $F_{0.99}(1,12) = 9.33$
*Significant at $\alpha = 0.01$

From Table 3, the obtained value of 94.26 for the linear component far exceeds the critical value at 99% level of significance, and linear being the only significant trend. Table 4 and Table 5 summarized all the mean values and the form of relationship for each treatment in experiment on the variety of orders. In that table, the negative amount of lateness is mean earliness, while the positive amount of lateness is mean tardiness.

From Table 4 and Table 5, it was observed that mean average throughput time for all of the production volumes, whether performed by forward scheduling or backward scheduling in both job shop and cellular layout were gradually increased from low to high number of orders. This was proved by the form of relationship for all of the production volumes, where positive linear trend is obtained in this case. However, the amount of increases is not significant. This is due to the set-up time used to reset the workstation when order changed is small.

On the other hand, mean lateness for all of the production volumes, whether performed by forward scheduling or backward scheduling in both job shop and cellular layout were slightly increased when the number of orders is increased. This was proved by the form of relationship for all of the production volumes, where positive linear trend is obtained for tardiness and negative linear trend is obtained for earliness in this case. Lateness only showed slightly increased when the number of orders is increased due to the increases of total set-up time is small.

However, mean labour productivity for all of the production volumes, whether performed by forward scheduling or backward scheduling in both job shop and cellular layout were gradually decreased from low to high number of orders. This was proved by the form of relationship for all of the production volumes, where negative linear trend is obtained in this case. The reduction of labour productivity from low to high number of orders for each production volume is due to worker have spent more time on set-up when the number of orders is increased until reduce the worker productive work.

It is observed that for all of the production volumes, backward scheduling is always performed better than forward scheduling in job shop, while forward scheduling is always performed better than backward scheduling in cellular layout due to the smallest average throughput time, lowest tardiness or highest earliness, and highest labour productivity its give.

It is also observed that cellular layout is performed better than job shop for all of the production volume due to the smallest average throughput time, highest earliness, and highest labour productivity cellular layout obtained. Thus, manufacturing firm should choose cellular layout in this case if make-to-order (MTO) production and inventory strategy are to be apply due to its ability to adapt the flexibility and variety of orders for different production volumes.

Table 4: Summary of test for trend for forward scheduling and backward scheduling in job shop – experiment on the variety of orders

Volume	Number of Orders	Mean Value and Response Trend for each Treatment											
		Dependent Variables											
		Average Throughput Time (min/unit)				Lateness (min)				Labour Productivity (unit/hour)			
		Forward		Backward		Forward		Backward		Forward		Backward	
		Mean	Trend	Mean	Trend	Mean	Trend	Mean	Trend	Mean	Trend	Mean	Trend
Low	5	1.1363	+ve Linear	1.1355	+ve Linear	-3982.17	+ve Linear	-3986.79	+ve Linear	4.8003	-ve Linear	4.8035	-ve Linear
	6	1.1376		1.1367		-3974.43		-3980.11		4.7948		4.7988	
	7	1.1379		1.1374		-3972.45		-3975.83		4.7934		4.7958	
	8	1.1392		1.1387		-3964.53		-3967.92		4.7879		4.7903	
Medium	9	1.1334	+ve Linear	1.1329	+ve Linear	-1733.09	+ve Linear	-1736.79	+ve Linear	4.8127	-ve Linear	4.8147	-ve Linear
	10	1.1342		1.1332		-1726.78		-1734.58		4.8094		4.8135	
	11	1.1348		1.1342		-1721.95		-1726.43		4.8068		4.8092	
	12	1.1355		1.1349		-1716.10		-1720.62		4.8037		4.8061	
High	13	1.1320	+ve Linear	1.1314	+ve Linear	519.71	+ve Linear	513.97	+ve Linear	4.8186	-ve Linear	4.8211	-ve Linear
	14	1.1322		1.1320		522.37		519.83		4.8175		4.8186	
	15	1.1325		1.1324		525.10		523.87		4.8164		4.8169	
	16	1.1334		1.1331		534.33		531.63		4.8124		4.8136	

Table 5: Summary of test for trend for forward scheduling and backward scheduling in cellular layout – experiment on the variety of orders

Volume	Number of Orders	Mean Value and Response Trend for each Treatment											
		Dependent Variables											
		Average Throughput Time (min/unit)				Lateness (min)				Labour Productivity (unit/hour)			
		Forward		Backward		Forward		Backward		Forward		Backward	
		Mean	Trend	Mean	Trend	Mean	Trend	Mean	Trend	Mean	Trend	Mean	Trend
Low	5	1.0030	+ve Linear	1.0038	+ve Linear	-4781.86	+ve Linear	-4777.31	+ve Linear	5.4381	-ve Linear	5.4340	-ve Linear
	6	1.0059		1.0062		-4764.74		-4762.47		5.4227		5.4207	
	7	1.0090		1.0103		-4746.22		-4738.20		5.4062		5.3990	
	8	1.0172		1.0156		-4696.94		-4706.50		5.3625		5.3709	
Medium	9	1.0080	+ve Linear	1.0086	+ve Linear	-2735.98	+ve Linear	-2731.45	+ve Linear	5.4113	-ve Linear	5.4082	-ve Linear
	10	1.0091		1.0101		-2726.99		-2718.96		5.4053		5.3999	
	11	1.0107		1.0111		-2714.20		-2711.25		5.3967		5.3947	
	12	1.0130		1.0143		-2696.16		-2685.77		5.3847		5.3778	
High	13	1.0117	+ve Linear	1.0127	+ve Linear	-683.28	+ve Linear	-673.10	+ve Linear	5.3917	-ve Linear	5.3862	-ve Linear
	14	1.0139		1.0159		-660.75		-641.02		5.3797		5.3692	
	15	1.0152		1.0164		-647.75		-636.20		5.3728		5.3667	
	16	1.0173		1.0187		-627.44		-613.05		5.3620		5.3545	

Impact of number of workers on scheduling approach

Summary of ANOVA are shown in Table 6 where lateness for high volume in cellular layout using backward scheduling is used as an example. The rest of the calculated F values are as presented in Table 7.

Table 6: Summary of ANOVA on lateness for high volume in cellular layout using backward scheduling

Source of Variation	SS	df	MS	F
Between SS	7831.62	4		
Within SS	26861572.67	10		
Treatment	26852220.19	2	13426110.09	11484.53*
Residual (Error)	9352.48	8	1169.06	
Total	26869404.29	14		

$F_{0.95}(2,8) = 4.46$, $F_{0.99}(2,8) = 8.65$
*Significant at $\alpha = 0.01$

Table 7: The calculated F value for experiment on the number of workers

Dependent Variable	Volume	Job Shop		Cellular Layout	
		Forward	Backward	Forward	Backward
Average Throughput Time	Low	6219.19*	5535.44*	5094.76*	4686.80*
	Medium	11976.12*	6707.04*	12368.53*	8074.46*
	High	22823.80*	19567.89*	22904.70*	11508.43*
Lateness	Low	6125.22*	5528.61*	5077.45*	4687.55*
	Medium	11911.32*	6731.71*	12479.79*	8065.27*
	High	22624.16*	19399.59*	22872.22*	11484.53*
Labour Productivity	Low	2007.36*	1784.65*	1803.58*	1605.23*
	Medium	4302.88*	2018.08*	3596.34*	2987.39*
	High	6932.66*	5901.10*	5793.47*	2953.02*

$F_{0.95}(2,8) = 4.46$, $F_{0.99}(2,8) = 8.65$
*Significant at $\alpha = 0.01$

From Table 7, it is indicated that all the calculated F value are significantly greater than the critical F value of 99% level of significance. Therefore, null hypothesis (H_0) is rejected and concluded that the effect of different number of workers on dependent variables are significant. The significant effect is occurred due to the different distribution of workload in job shop and cellular layout when the number of workers is not same until alter the dependent variables.

The simulation results were further tested by test for trend to determine the response trend between independent variable and dependent variable using orthogonal polynomials. Table 8 and Table 9 summarized all the mean values and the form of relationship for each treatment in experiment on the number of workers.

From Table 8, the mean average throughput time and lateness of both forward scheduling and backward scheduling in job shop for all of the production volumes will significantly decreased when 1 worker have been added, and it will only slightly increased when 1 worker have been reduced. The scenarios is different in cellular layout, where from Table 9, the mean average throughput time and lateness of both forward scheduling and backward scheduling for all of the production volume will only slightly decreased when 1 worker have been added, and it will significantly increased when 1 worker have been reduced. The different scenarios of these are due to the different distribution of workload in job shop and cellular layout. The workload in job shop is not balanced. The cycle time of initial bottleneck in job shop which is soldering shop is higher than the cycle time of chassis shop. Although the reduced of one worker from chassis shop will caused that shop become a new bottleneck, but the different time between the initial bottleneck and new bottleneck is small. Thus, average throughput time and lateness is just slightly increased when one worker is absent. However, additional of one worker into the bottleneck of job shop will significant reduced the worker workload and cycle time of that shop and hence greatly reduced the average throughput time and lateness. The case is different in cellular layout, where the workload of workers is balanced. The workload of the reduce worker will be take over by other workers within cell 3, which will increased the workload of workers in that cell and become a bottleneck until significant increased the average throughput time and lateness. However, although additional of one worker into the bottleneck which is cell 4 will reduced the workload of workers in that cell and shifted the bottleneck to another cell, but the cycle time of initial bottleneck and new bottleneck will be not much different. Hence, average throughput time and lateness will only slightly decreased when one worker is added.

From the observation of Table 8, mean labour productivity for both forward scheduling and backward scheduling in job shop is decreased when the number of workers is reduced from 12 workers to 11 workers, and then increased when the number of workers is further reduced from 11 workers to 10 workers. The trend is different for both scheduling approach in cellular layout as showed on Table 9, where the mean labour productivity is increased when the number of workers is reduced from 12 workers to 11 workers, and then decreased when the number of workers is further reduced from 11 workers to 10 workers. This was proved by the form of relationship for all of the variety orders, where negative quadratic trend is obtained in job shop, and positive quadratic trend is obtained in cellular layout. These scenarios is due to the different workload of workers were distributed in the layout for each different number of workers. All of these different layouts were developed according to the criteria of job shop and cellular layout. It is impossible to balance the workload of workers in each layout if the criteria of job shop and cellular layout are to be met.

It is observed that all of the production volumes for each of the number of workers, backward scheduling is performed better than forward scheduling in job shop, while forward scheduling is performed better than backward scheduling in cellular layout due to the smallest average throughput time, lowest tardiness or highest earliness, and highest labour productivity its give.

It is noticed that all the number of workers in job shop and cellular layout are able to complete the low and medium volume on time, but only the 12 workers layout for job shop, and 11 and 12 workers layout for cellular layout are able to complete the high volume on time. Thus, cellular layout of 11 workers is the best choice to be used by manufacturing firm to achieve make-to-order (MTO) strategy because it involved the less number of workers while can produce the different volumes on time.

Table 8: Summary of test for trend for forward scheduling and backward scheduling in job shop – experiment on different number of workers

Volume	Number of Workers	Average Throughput Time (min/unit)				Lateness (min)				Labour Productivity (unit/hour)			
		Forward		Backward		Forward		Backward		Forward		Backward	
		Mean	Trend	Mean	Trend	Mean	Trend	Mean	Trend	Mean	Trend	Mean	Trend
Low	10	1.1381	-ve Linear	1.1376	-ve Linear	-3971.59	-ve Linear	-3974.68	-ve Linear	5.2721	+ve Quadratic	5.2745	+ve Quadratic
	11	1.1363		1.1355		-3982.17		-3986.79		4.8003		4.8035	
	12	0.9831		0.9810		-4901.12		-4914.05		5.0857		5.0969	
Medium	10	1.1352	-ve Linear	1.1354	-ve Linear	-1718.25	-ve Linear	-1716.88	-ve Linear	5.2854	+ve Quadratic	5.2845	+ve Quadratic
	11	1.1334		1.1329		-1733.09		-1736.79		4.8127		4.8147	
	12	0.9835		0.9801		-2932.24		-2959.25		5.0840		5.1016	
High	10	1.1347	-ve Linear	1.1336	-ve Linear	546.83	-ve Linear	536.12	-ve Linear	5.2878	+ve Quadratic	5.2928	+ve Quadratic
	11	1.1320		1.1314		519.71		513.97		4.8186		4.8211	
	12	0.9789		0.9794		-1010.74		-1006.08		5.1077		5.1052	

(Table header spanning all dependent variable columns: Mean Value and Response Trend for each Treatment — Dependent Variables)

Table 9: Summary of test for trend for forward scheduling and backward scheduling in cellular – experiment on different number of workers

Volume	Number of Workers	Average Throughput Time (min/unit)				Lateness (min)				Labour Productivity (unit/hour)			
		Forward		Backward		Forward		Backward		Forward		Backward	
		Mean	Trend	Mean	Trend	Mean	Trend	Mean	Trend	Mean	Trend	Mean	Trend
Low	10	1.2931	-ve Linear	1.2888	-ve Linear	-3041.37	-ve Linear	-3067.20	-ve Linear	4.6401	-ve Quadratic	4.6556	-ve Quadratic
	11	1.0030		1.0038		-4781.86		-4777.31		5.4381		5.4340	
	12	0.9940		0.9938		-4836.01		-4837.34		5.0302		5.0313	
Medium	10	1.2937	-ve Linear	1.2957	-ve Linear	-450.38	-ve Linear	-434.80	-ve Linear	4.6379	-ve Quadratic	4.6310	-ve Quadratic
	11	1.0080		1.0086		-2735.98		-2731.45		5.4113		5.4082	
	12	1.0009		1.0039		-2792.64		-2768.91		4.9955		4.9807	
High	10	1.2909	-ve Linear	1.2933	-ve Linear	2108.51	-ve Linear	2133.40	-ve Linear	4.6481	-ve Quadratic	4.6392	-ve Quadratic
	11	1.0117		1.0127		-683.28		-673.10		5.3917		5.3862	
	12	1.0033		1.0064		-766.69		-735.56		4.9834		4.9680	

(Table header: Mean Value and Response Trend for each Treatment — Dependent Variables)

Conclusion

The optimum scheduling approach for a manufacturing firm in this research is the ability to have the lowest average throughput time, lowest tardiness or highest earliness, and if possible highest labour productivity. It is noticed that the performance of scheduling approach is different in each layout. No matter in what conditions, backward scheduling in job shop always has the lowest average throughput time, lowest lateness, and highest labour productivity than forward scheduling. In other word, backward scheduling always performed better than forward scheduling in job shop. On the other hand, forward scheduling in cellular layout always has the lowest average throughput time, lowest lateness, and highest labour productivity than backward scheduling in all conditions. This showed that forward scheduling always performed better than backward scheduling in cellular layout.

From the results, it can be concluded that the manufacturing firm should use the 11 workers cellular layout to produce the radio cassette player if make-to-order (MTO) strategy is to be implemented due to its ability to adapt the flexibility and variety of orders in all production volumes. Forward scheduling is the best choice since it's performed better than backward scheduling in cellular layout.

For future work, this project can be continued by including the just-in-time (JIT) scheduling rules and compare its performance with forward scheduling and backward scheduling. Earliness or tardiness penalties can be used as the dependent variables in this case to study their effect to scheduling approach. Two-way analysis of variance can be used to analyze the results since its permits the simultaneous study of two factors or variables.

Financial Statement

UNIT KUMPULAN WANG AMANAH
UNIVERSITI SAINS MALAYSIA
KAMPUS KEJURUTERAAN
SERI AMPANGAN
PENYATA KUMPULAN WANG

DR ZALINDA OTHMAN

304.PMEKANIK.6035121

TEMPOH BERAKHIR 21/03/2007

SCHEDULING WITH ALTERNATIVE MACHINE USING FUZZY INFERENCE SYSTEM &

JUMLAH GERAN :-

NO PROJEK :-

Tempoh Projek:01/09/2004 - 31/08/2006

PANEL :- J/PENDEK

PENAJA :-

Vot	Peruntukan (a)	Perbelanjaan sehingga 31/12/2006 (b)	Tanggungan semasa 2006 (c)	perbelanjaan Semasa 2007 (d)	Jumlah Perbelanjaan 2007 (c + d)	Jumlah perbelanjaan Terkumpul (b+c+d)	Baki Peruntukan Semasa (a-(b+c+d))
11000 GAJI KAKITANGAN AWAM	4,919.00	5,727.00	0.00	0.00	0.00	5,727.00	(808.00)
21000 PERBELANJAAN PERJALANAN DAN SARA	2,080.00	205.40	0.00	0.00	0.00	205.40	1,874.60
23000 PERHUBUNGAN DAN UTILITI	346.00	28.00	0.00	0.00	0.00	28.00	318.00
27000 BEKALAN DAN ALAT PAKAI HABIS	2,350.00	249.00	0.00	0.00	0.00	249.00	2,101.00
29000 PERKHIDMATAN IKTISAS & HOSPITALITI	0.00	2,957.00	0.00	0.00	0.00	2,957.00	(2,957.00)
35000 HARTA-HARTA MODAL LAIN	6,000.00	5,999.00	0.00	0.00	0.00	5,999.00	1.00
	15,695.00	15,165.40	0.00	0.00	0.00	15,165.40	529.60
Jumlah Besar	15,695.00	15,165.40	0.00	0.00	0.00	15,165.40	529.60

List of Publications

A PRELIMINARY STUDY ON LAYOUT DESIGN BASED ON MAKE TO ORDER ENVIRONMENT

Noor Ain Ibrahim[1], Zalinda Othman[2] and Khairanum Subari[3]
School of Mechanical Engineering, Universiti Sains Malaysia, Engineering Campus, Seri Ampangan, 14300 Nibong Tebal, Penang, Malaysia.
E-mail: [1]narien@yahoo.com, [2]zalinda@eng.usm.my,[3]meanum@eng.usm.my

Abstract
Layout design is the process to devise a good, workable and effective arrangement of the resources of a unit. It is the organization of the company's physical facilities to promote the efficient use of the company's resources such as people, equipment, material and energy. It affects the productivity and profitability of an organization more than almost any other major corporate decision. The importance of the layout design becomes readily obvious when one realises that in addition to the need for new manufacturing facilities; existing plants undergo some changes continually. Regarding to the above matter, this paper proposes a preliminary study on developing new layout design procedures for MTO organizations based on existing procedures. First phase of this research is a distribution of questionnaires to obtain the overall overview of the manufacturing environment in Malaysia. In this era, manufacturers are looking forward to run the low-as-possible inventory operation and delivered their products immediately. Many manufacturers are going towards Make-to-Order (MTO) environment as a suitable strategy to reduce lead-time and the level of inventory. The second phase will be a case study in MTO organization to collect data. The data will be evaluated using WITNESS simulation and a new design will be proposed in the final phase of this research.

Keywords: Layout design, layout procedures, Make-to-Order, simulation

1. INTRODUCTION

Only an efficient and productive organization can survive in today's competitive market. Company must focus on moving products quickly through the manufacturing system. Therefore, all facilities design and layout must be enacted quickly, accurately and effectively. The way company chooses to design its facility layout has a direct implication for the relative emphasis place on different competitive dimension. The ability to compete is being determined by the degree of responsiveness to customers and key markets, which are bringing products quickly to market, the quality of the products, and exceed customer expectations. The faster parts flow through the company's facility layout, the faster it can respond to the demands of the market.

Facility layout design is describe as a set of practices for organizing company's physical facilities by promoting efficiency in the use of company's resources such as people, equipment, material and energy (Meyers & Stephens, 2000). These practices include making decision on the location of plant, plant layout, and selection of suitable material handling. The physical arrangement of machines, workstations, people, location of raw materials and material handling equipment, is known as the layout (Meyers & Stephens, 2000). In addition, facility layout under the manufacturing concept can be defined as "the process of obtaining the optimal disposition of the physical facilities for a manufacturing unit" (El-Rayah & Hollier, 1970). Facility layout is concerned with the physical location of the production processes within each facility. The basic objective of designing a layout is to ensure a smooth flow of work, material, and information through the system.

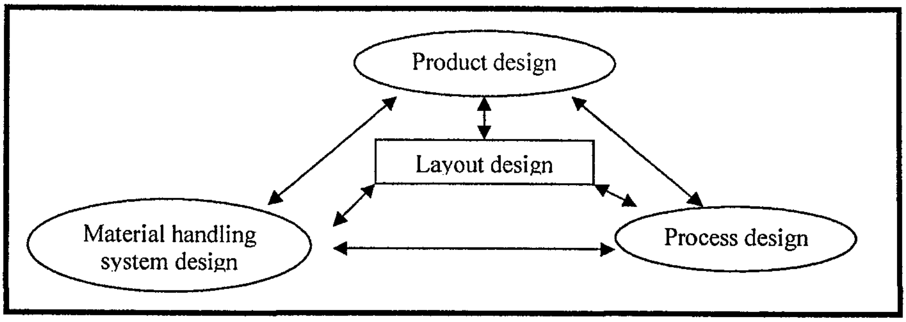

Figure 1 Communication links among product, process, material handling and layout design (Francis and White, 1974)

Layout design has close relationships with product design, process design and also material handling system design. The relationship can be summarized in Figure 1. Product design is responsible for taking input from marketing and for building a product. Process design includes specification of operational sequences needed to transform raw material into finished product. Material handling is related to systems or moving parts, tools and scrap.

One of the most effective methods for increasing productivity and reducing costs is to reduce or eliminate all activities that are unnecessary or wasteful. A facility design should accomplish this goal in terms of material handling, personnel, equipment utilization, reduced inventories, and increased quality (Zeydan & Golec, 2004). A poor design layout will result in poor productivity, increased work in process, disordered, material handling, and others (Wang et al., 2001). Layout decisions once made and implemented are not easy to change. Changing the layout design is a long-term, costly proposition, and any modifications or rearrangement of an existing plant represents a large expense both in terms of relocation and lost processing time and can usually not be accomplished easily (Sule, 1994). Once set up it would be very costly to rearrange them. Therefore, layout decisions are medium to long term in their effect. So, it is important to get the most efficient layout in the first place and to build-in some flexibility. There are a lot of factors that can influence a manager's decision to change a layout, such as very high cost of production, lack of utilization and high material handling costs (T. Akright & E. Kroll, 1997). There are two major tasks for the engineers whether to redesign the existing layout to meet current market demands or design a new plant from the scratch (Kyle & Ludka, 2000). Redesign can be highly expensive and disruptive, especially when the entire factory and production have to be shut down and stopped.

Make-to-Order (MTO) environment

MTO is defined by Kingsman et al. (1993) as organizations that manufacture different items for particular customers when demand is unpredictable and when the customer lead time permits the production process to start on receipt of an order. The MTO companies can be grouped into two types on the basis of customisation by individual order or customisation by contract and manufactures products due to customer specification (Muda & Hendry, 2002). It means assumes that all the engineering and design are complete and the production process is proven but the systems are not appropriate for all types of products. Some factors have to be considered when evaluating the prospect of MTO which are value of a custom product, customer patience, cost of stock outs, inventory holding costs, modularity, and manufacturing lead time and set-up costs. Besides that, there are a few keys to succeed in MTO environment from the perspectives of marketing (Navas, 2003):

1. Forecast demands for numerous products, customers and markets.
2. Monitoring supplies across multiple sites including external partner locations, matching supplies to prioritized demands.
3. Global trading compliance with trading rules and restrictions.
4. Employee and trading partner access to relevant data, applications and services – regardless of location or computing platform.
5. Efficient management of warehouses and transportation that ensures on time delivery at the lowest cost.
6. Flexible, real-time management of customer and partner relationships.

Traditional approaches in layout design

Over the years, several new layout procedures have evolved to assist the planner in designing layouts. Few of the major traditional approaches which have strongly influenced the development of the layout design process were Apple's Plant Layout Procedure (Apple, 1963), Reed's Layout Procedure (Reed, 1967) and Systematic Layout Procedure Planning (Muther, 1973). Apple, Muther and Reed, the famous leaders in the field of plant layout throughout the 1960s and 1970s, all favoured using design skeleton first to choose the overall configuration of the layout, then transposing the design skeleton into actual layouts (Sly et al, 1996). SLP is widely used even it was developed in late 1960s. It was based on two methods developed by Reed and Apple and is still famous until today because of the simple step-by-step approach to facility design and also became the basis for many layout design techniques and software tools. The early forms of design skeletons were flow graphs and space relationship diagrams. This space relationship diagrams are the core of Muther's SLP methodology. Muther and Hales (1979) identified three fundamentals in layout planning, which are relationships, space and adjustments and then they developed the SLP methodology. This manual layout procedure combines capacity decisions, departmentalization and decisions concerning the location of department within the layout. SLP procedure can be used at the block (department) level or the detail (machine) level.

2. METHOD

This research is conducted in three phases. Phase 1 is a random distribution of questionnaires to 200 industries in Malaysia involving multinational and small, medium industries (SMI). This survey is to obtain the overview of the manufacturing in Malaysia, the company profile and the awareness about the manufacturing concepts especially that related to layout. Phase 2 involved a case study in MTO organization. Data regarding the layout design will be gathered and simulation is used to find the best layout. A few alternatives layout will be proposed to the organization. The next phase is simulation using WITNESS software. All the data from the case study are simulate to find the best design of layout.

3. RESULT AND DISCUSSION OF PHASE 1

The data from the questionnaires was analyzed using Statistical Package for the Social Sciences – SPSS for Windows (Kinner & Gray, 1999). Data was analyzed efficiently because the response to the questions in the questionnaire was encoded into system using numbers that represent the real data. 200 set of questionnaires were sent randomly to manufacturers in Malaysia. 45 questionnaires were answered by the organizations but three of them were not completed. Therefore, only 42 questionnaires were used for analysis. Refer to the Figure 2 below, 52% of the manufacturers are MTO while 36% are not while 12% did not response to the question. From the survey, steel industry, automative industry and also rubber or polymers industry are mostly MTO organizations. Most of them are private/local OEM (Original Equipment Manufacturer) and multinational.

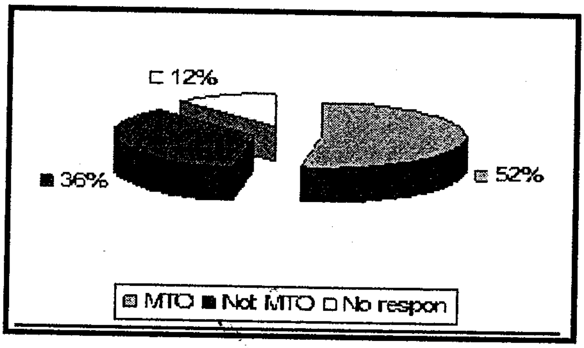

Figure 2 Environment in Malaysia

From the 52% of the MTO organizations, analysis on the inventory level, lead time, cycle time, setup time reduction and also the shop floor determination was carried out. As mentioned before, one of the objectives in MTO is to reduce the level of inventory. From the pie chart in Figure 3, it shows that 50% of the organizations agree while 18% strongly agree that reducing the level of raw material inventory is important in their organizations. In Figure 4, 46% agree and 5% strongly agree that the low of level inventory in their final products is important. Pricing pressures combined with the need to increase profitability have historically moved many manufacturers to run a lean, low-as-possible inventory operation (Navas, 2003). As for the final products, they can be delivered to the customers as soon as the products were made. This can reduce customer lead time and increase the customer satisfaction through on time delivery.

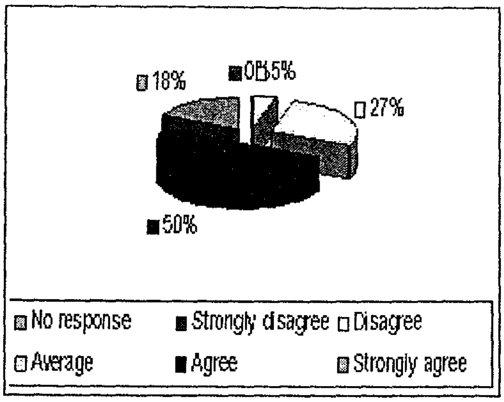

Figure 3: Level of raw material

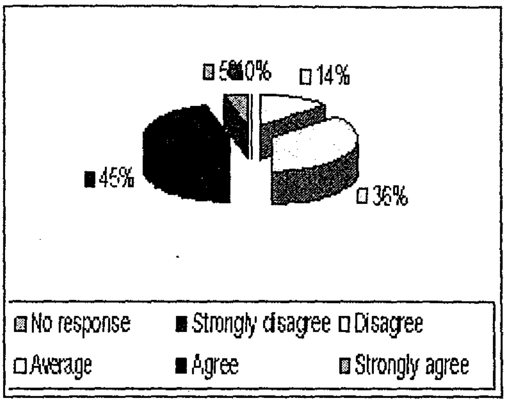

Figure 4: Level of product inventory

Based on the analysis, it was shown that the manufacturers agreed that they have to improve their processes to reduce lead time, setup time and cycle time as shown in Figure 5,6 and 7. Lead time depends on the current work-in-process in the shop, which in turn a consequence of the ratio of delivered orders to released orders. It affects the safety level of stocks in finished goods inventory and increased the inventory which against the principles of MTO. In order to reduce cycle time, the key parameter is the inventory level. There are many other major contributors that affected cycle time besides inventory level such as scheduling, capacity, layout and others. Layout can effects machine utilisation, staffing, work in process distribution, walking distance and material handling. High cycle time introduces inefficiency and increase time-to-market.

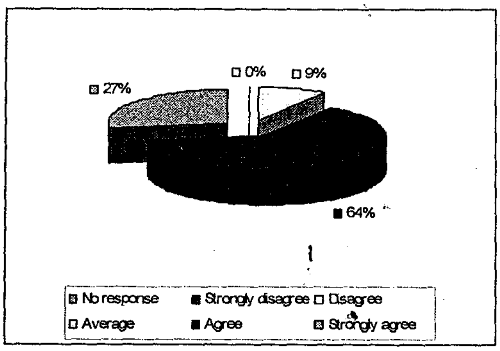

Figure 5: Setup time

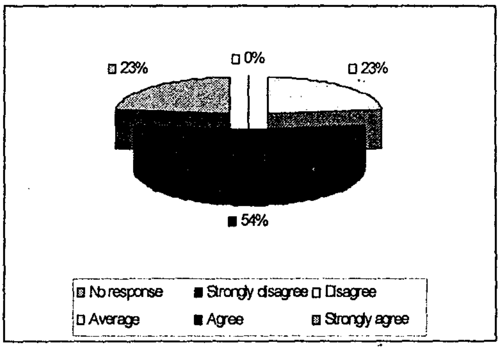

Figure 6: Lead time

Based on the definition, layout design based on the product flow. Figure 8 shows that 41% of the MTO organizations agreed that layout of their production also refers to the product flow to minimize the distance between sequential operations. Simplifying the shop floor operations and systems can made manufacturers get closer to their customers. Simplify the shop floor is one of the MTO 14 world class principles (Muda & Hendry, 2002).

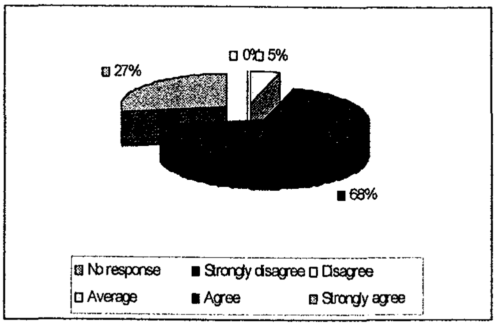

Figure 7 : Cycle time

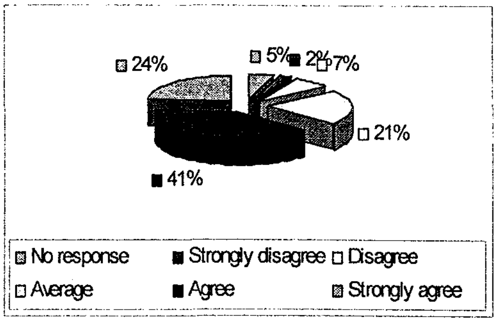

Figure 8 : Shop floor

4. CONCLUSION

Important considerations in today's manufacturing environment are demand's low inventories, high levels of flexibility and shorter lead time. These elements enhance the manufacturers to develop new manufacturing strategy that meets these criteria. MTO is one of the strategies and layout design plays an important role in achieving these targets. However, to design, redesign, improvement and implement a layout need a lot of time, and high investment of money in long term period so the companies have to plan very well in order to get the best results.

Some of the impacts of an effective layout are to eliminate bottlenecks, increase capacity, minimise material handling costs, reduce manufacturing cycle time and customer service time, utilise labour and space efficiently. To achieve the successful implementing for layout design, the key factors are commitment at all level, training / flexibility of the team clear defined responsibilities/accountabilities, detailed planning up front, recognition in the cell of their role as customer and supplier, communication of objectives, simple performance monitors, and appropriate control at low level.

This preliminary study shows that the manufacturers in Malaysia aware that in order to improve their processes, they should reduce lead time, inventory level, setup time and cycle time. One way to achieve these targets is through layout design.

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A COMPARATIVE STUDY OF FLEXIBLE ASSEMBLY LINE AND MIXED MODEL ASSEMBLY LINE

[1]Fawad Ahmed, Dr. Zalinda, Dr Khairanum Subari, Dr Arif Sohail
School of Mechanical Engineering, University Science Malaysia
14300 Nibong Tebal, Pulau Pinang, Malaysia
E-mail: [1]Fawadusm@yahoo.com

Abstract
Now-a-days mixed model assembly line is widely used in manufacturing industries to produce many different models without carrying large inventory. Various authors suggested different technique in mixed model assembly line. As Monden goal chasing method is concerned to keep continue consumption of the parts in mixed model assembly line as it follows the just in time (JIT) philosophy. The present study focuses on the simulation of flexible assembly line and mixed model assembly line with the objective of achieving minimum production cost and to keep constant parts consumption. It is considered that parts are delivered on zero lead time basis. In this case if parts becomes Zero or less than production requirement then order is placed again. Thus holding coast of parts is a crucial factor which depends on the time of order placed. Flexible assembly line involves setup cost whereas in mixed model assembly line there is no setup cost. Present study focuses on to analyse the effect of different cycle time, setup time, model sequences, and its effect on holding cost of models, ordering cost of parts, penalty cost for finished goods and etc is analysed.

Keywords: Flexible assembly line, Mixed model assembly line, Simulation, JIT

INTRODUCTION

An assembly line of a plant consists of models of product, parts for assembling the models and line setup for different models. To produce various types of models, various types of parts are required. Some parts are common for each model and some are fitted exclusively in models. When assembly line produces the finished goods higher than the daily production demand, then it adds up the holding cost of finished goods. On the other hand if production is less than daily demand then penalty is imposed on surplus models. In the same way, if ordered quantity of parts is higher than production then holding costs of parts increases. Let us take an example from an automobile plant to understand all the discussed aspects raising the cost. An automobile plant produce different model i.e. A1, A2.....M and different parts are used in these models like P1, P2.......N. Some parts are used in each model and some parts are used in a particular model. Procurement department of this plant kept constant order quantity of parts. They place the order when the parts inventory status doesn't meet the production. Parts are delivered on zero lead time basis Procurement department put constant order size, after consumption of the parts, it is observed that ending stock of parts is high every day raising holding cost. In assembly line they produce different models. It is usual that the model 1 meets the daily production target, while Model 2 does not meet the daily production target and so on. Holding cost for model is zero, however penalty cost for not delivering the model 2 is applied.

LITERATURE REVIEW

In considering mixed model assembly line problems, the following assumptions are made. These assumptions are based on different authors, to keep the constant usage of every part used in the assembly line. This goal is a good way of fitting the just in time concept in Toyota's production system. In all of Toyota's goal oriented studies a consideration which has not been explained explicity in the literature is that all parts of a given product are assumed to be used at the epoch into the assembly line with zero length. For an assembly line with multiple work stations, it is clear that the parts of a given product are used at different epochs subsequent to originally feeding this unit into it.This paper discusses about Toyota's goal of sequencing mixed models on an assembly line with multiple workstations, however the sequencing problem is formulated based on defining the ideal usage rate of a part as the requirement for the part per time period. To resolve this sequencing problem they proposed modified goal chasing algorithm. Their proposed not deals with the goal to keep the constant usage of every part used in assembly line, known as Toyota's goal. The purpose of this goal is to smooth production, so as to minimize the variation in production, so as to minimize the variation in production quantities and the work in process inventories in preceding processes. This goal is a good way of fitting the JIT concept in the Toyota production system. Since the mid 1980's the success of the Toyota Production System has increased the importance of this goal [1].

A mixed model assembly manufacturing operating in a pull production environment can be controlled by setting a production schedule only for the last process in the facility which is usually an assembly line of mixed model type. In the mixed-model sequencing problems, two major goals are considered , one is smoothing the workload on each workstation on the assembly line and second is to keep a constant rate of usage of all parts used on the assembly line. They studied about first some well known solutions approaches with goal 2 are analyzed through minimizing the sum-of-deviations of actual production from the desired amount [2].

A dynamic part-feeding system for an automotive assembly line. The part feeding system at an assembly shop controls the feeding of parts from the warehouse to workstations of the assembly shop in accordance with the production of vehicles. The part-feeding system plays a crucial role in determining the level of the inventory and stockout rate at the automotive assembly line. They proposed a dynamic part-feeding system for an automotive assembly plant which estimates the part consumption amounts dynamically considering the actual production progress and directs the feeding orders dynamically to feeders. The result of a simulation show that the proposed dynamic feeding system products better results than a static feeding system. Production at an automotive assembly plant is a typical example of the mixed model assembly so that numerous types of vehicles are produced alternatively on the same assembly line. Normally an automobile assembly plant consist of the main line of the body, painting, assembly shops and several sub-lines feeding parts to the main line. The daily production sequence is dispatched to the body shop and the production of the whole

automotive assembly plant is processed according to the daily production sequence. Bodies are built by the welding robots in the body shop and stored in a buffer named white body storage (WBS) before being fed into the painting shop. Then body pass several body processed according to the daily production sequence. Bodies are built by the welding robots in the body shop and stored in a buffer named painted body storage (PBS) before being fed into the assembly shop. Also based on the production plan, purchase orders are issued to vendors. Vendors supply parts to the assembly plant according. Parts supplied by vendors are stored in a warehouse near the assembly shop. In the automotive industry, diversification of customer needs brings increase in the number of parts consumed, which causes disturbances in the production and logistics processes, inducing complication of the management. In the automotive industry, diversification of customer needs increases the number of parts consumed, which causes disturbances in production and logistics processes, inducing complication of the management. In this study, they proposed and prototyped a dynamic part-feeding system, which estimates the part consumption amounts dynamically considering the actual production progress and directs the feeding orders dynamically to feeders. The results of a simulation showed that the proposed dynamic feeding system produces better results than the static feeding system in terms of the level of inventory and the utilization of feeders. [3].

Worked to resolve the problem of production planning and they assumed each model has a given range of production days within the planning horizon and constant parts consumption The just-in-time (JIT) production concept suggests that a level, mixed model production schedule be repeated daily on an assembly line. Production schedule gives such advantages as smooth materials requirement, more balanced work loads on the assembly line, and better delivery performance meeting the demands of various models. And they have studied the problems to scheduling the production quantities. This schedule (or production planning) problem needs to be addressed prior to sequencing a mixed model assembly line. They considered that the demands of various models are known during a planning horizon. For a mixed model assembly line, the quantity of each model to be produced in each time period needs to be determined. In a simple case where the only condition is to meet the total requited production quantities within the planning horizon [4].

Make to order production policy, which reduces the customer lead time and is expressed in a random arrival sequence of different model types to the line. Additional common characteristics of such mixed model lines in a make-to-order environment are small numbers of work stations, a lack of mechanical conveyance and highly skilled workers. The design problem of mixed model assembly lines in make-to-order environment is address in this paper. [5]

Minimization of the two-stage variation in the mixed model assembly-sequencing problem of reducing the part level variation is transformed to product-level terms. The development is based on an existing simplification of the one-stage part level variation, a simplification of the two-stage part level variation, and the usage of a relationship matrix that evaluates the relevance among the product structures of various models Algorithms based on these simplification and transformation are presented, but the results in a smaller empirical computational results show that the transformed two-stage algorithm significantly outperforms the direct enumeration method in computation time for a large problems, and generally outperforms the one-stage method in mean squared deviation. The transformed two-stage method can be used as a heuristic procedure or as an intermediate tool for another solution approach. A more general sufficient condition than the existing condition than the existing condition for the equivalence of the problems of minimizing the product-level variation and minimizing the part level variation is also presented. The just-in-time (JIT) production system originated in the Toyota Motor Corporation has been widely applied. To achieve the smooth part usage rates, workload balance, and reduced finished-goods inventory in JIT production, many manufacturing firms have adapted mixed-model assembly line, areas needing to be addressed include line balancing and mixed model sequencing. For the problem of sequencing mixed model assembly lines, there have been two primary groups of commonly accepted goals: those related to leveling work loads for every part used on the line (goal 1), and those related to keeping a near constant usage rate every part used on the line (goal 2) JIT usually operates as a pull system. In order to meet demands promptly at every level in a pull system while maintaining a low inventory, significant fluctuations [6]. In materials requirement need to be avoided. Therefore the variation in the requirements of parts supplied by the preceding processes of the assembly line should be minimized (Monden, 1993). To accomplish this, the primary goal of sequencing a mixed model assembly line in the Toyota is to keep the consumption rates of all parts as close to constant as possible. Toyota developed GC 1 and GC 2 methods(Monden, 1993) Bautista et al (1996) presented several goal-chasing method improvement including a transformed approach that uses model terms in minimizing the one-stage variation, an approach, an approach that further considers the two-stage variation, and a rate –preserving approach to prevent the impoverishment of the remainder sequence. Bautista et al. also presented a bounded dynamic programming procedure to obtain either optima or heuristic solutions to the problem of minimizing the variation in part usage rates.

Miltenburg (1989) addressed the mixed model sequencing problem by considering the variation in production rates of the finished products. Under the assumption that all models require the same number and mix of parts, Miltenburg pointed out that minimizing the variation in production rates of the finished products (the product-level problem) achieves minimizing the variation in part usage rates(the part level problem). Miltenburg's algorithm reduces the product level variation in production rates through enumerating all product-level, two stages variations in modifying a potentially infeasible initial sequence stated that all models requiring distinct parts is another sufficient condition for equivalent for the equivalence of the product level and part level problems. conducted a comparison study with the goal chasing methods on different product structures. For the moderate structure studied in the experimentation. Goal chasing-1 obtained better results in terms of parts usage variation.

A mathematical formulation is presented which considers the difference between their model and traditional models. A heuristic that minimizes the number of stations for a predetermined cycle time is developed consisting of three stages; the balancing of a combined precedence, balancing each model type separately subject to the constrains resulting from the first stage, and a neighborhood search based improvement procedure.

Table - I

	By mathematical formulations	By programming
Ordering cost of parts	126.92	126.92
Set up cost	6.46	6.46
Holding cost of finished goods	1040	1040
Holding cost of parts	--	42.96

RESULTS AND DISCUSSION

To compare the different cost in mixed model assembly line and flexible assembly line, different sequences as given in table-II are considered for both lines. The cycle time and set up time are [15, 20] and [10, 15] respectively for model 1 and 2.

Table II

Sequence order	Model_1	Model_2
1	4	6
2	6	9
3	8	12
4	10	15
5	12	18
6	14	21
7	18	27
8	20	30
9	24	36
10	28	42

Figure 1-6 shows the different costs incurred for flexible assembly line for different production sequences. It is clear from figure 1 that the total production cost is minimal when production sequence is [10, 15] and maximum for sequence [4,6]. The holding cost is zero for sequence no 1-4 and penalty is zero for sequence no 5-10. The holding cost of parts is not affected much for sequence 1-10. Figure 6 shows that flexible assembly line gives increased cost for ordered parts for sequence 1-10 but in case of mixed assembly line this cost is remained constant for cycle time [20, 20], [21, 21] and [22, 22]. Figure 7-12 shows the simulation of mixed model line for cycle time of [20, 20]. The minimum cost is achieved when sequence is [10, 15].

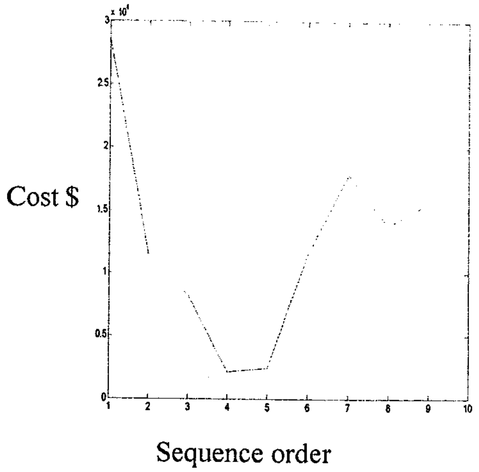


Figure-1 Avg total cost of production for 2000 days

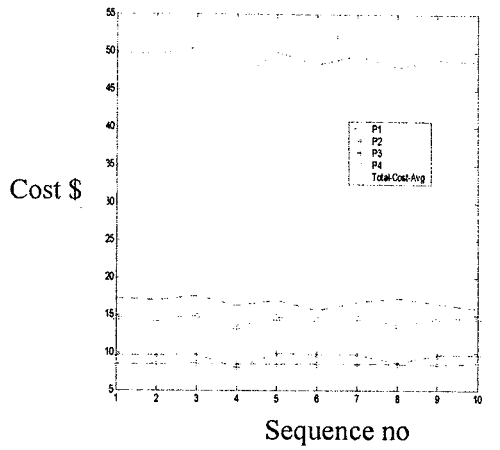


Figure-4 Avg total parts holding cost for 2000 days

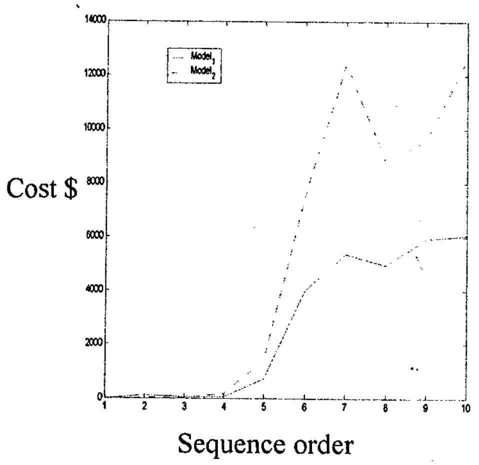


Figure-2 Avg Holding cost of models for 2000 days

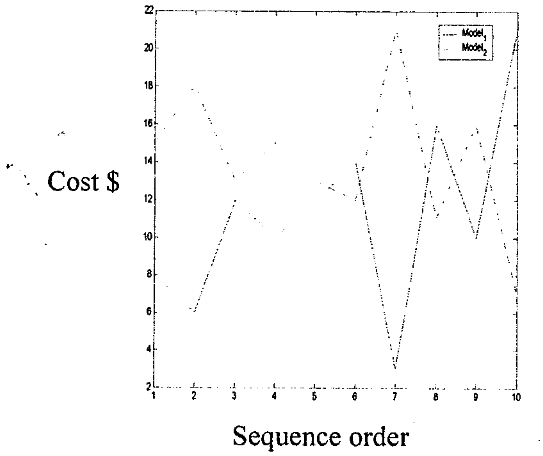


Figure-5 production on 2000th day

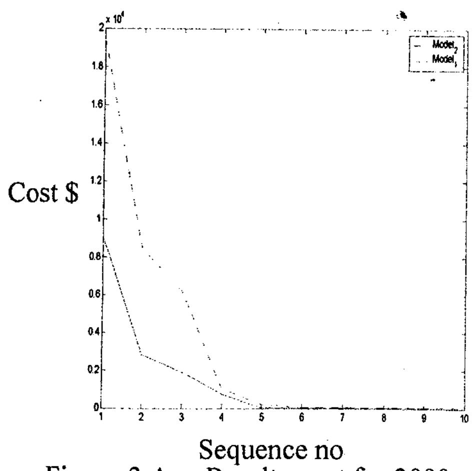


Figure-3 Avg Penalty cost for 2000 days

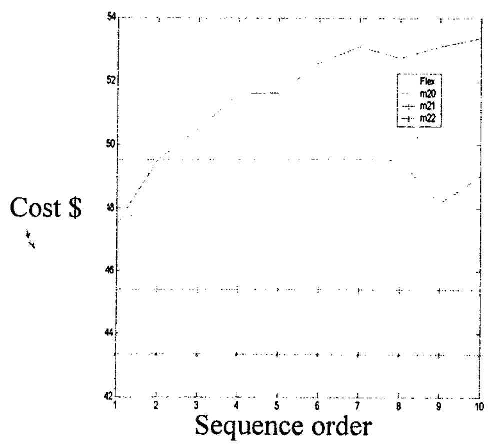
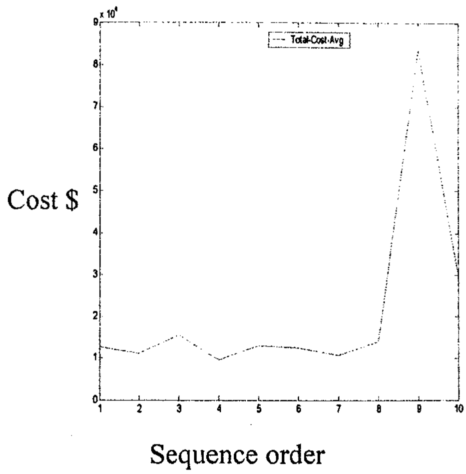
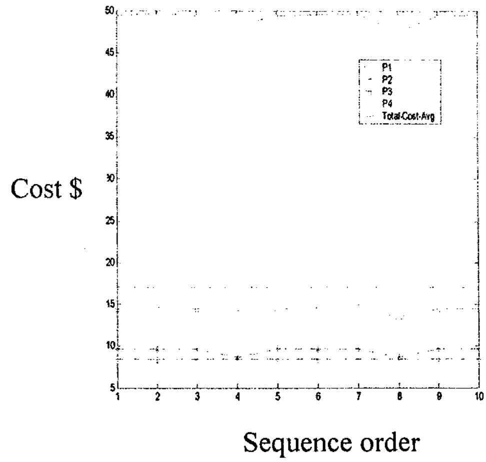


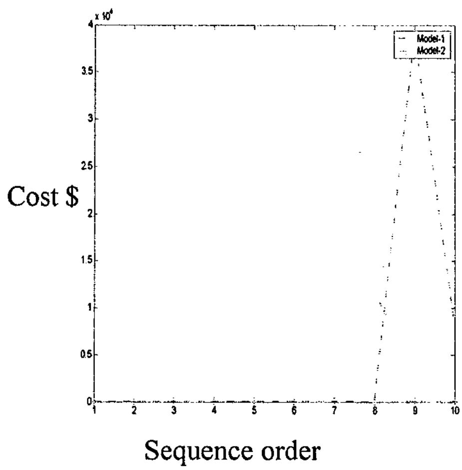
Figure-6 Avg total parts order cost for 2000 days



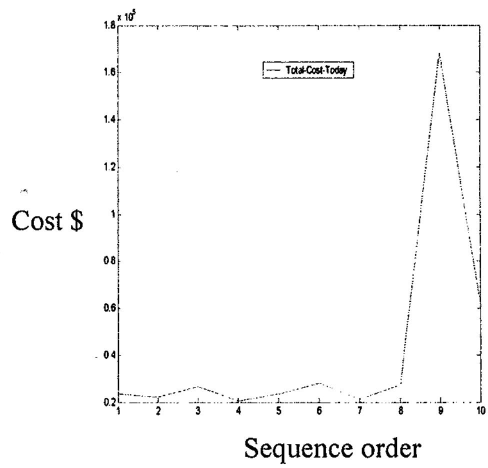
Figur-7 Avg total cost of production for 2000 days



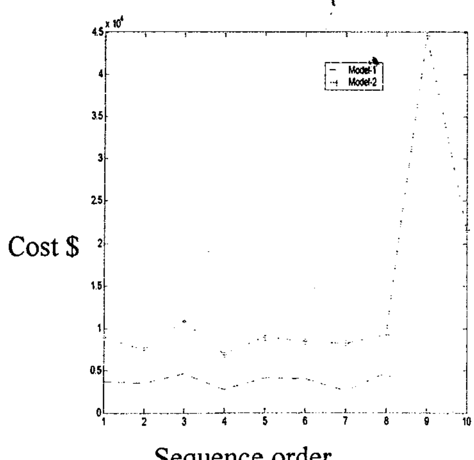
Figur-10 Avg total parts holding cost for 2000 days



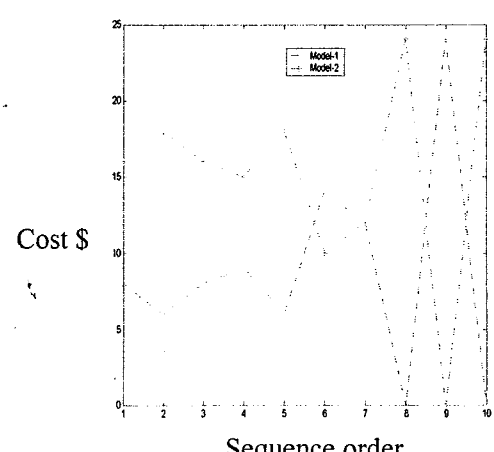
Figur-8 Avg Holding cost for 2000 days



Figur-11 Avg total cost of production on 2000th days



Figur-9 Avg Penalty cost for 2000 days



Figur-12 production on 2000th day

CONCLUSION

The basic purpose of developing the cost modeling is to diagnose and reduce the different cost in flexible assembly line and mixed model assembly. A computer code is developed to analyse the different costs involved. It is seen that parts ordering cost is not much affected in case of mixed model assembly line where as it increase with increase in model quantity for flexible assembly line. Via simulation it is shown that the different costs involved in the production are strong function of sequence chosen and minimum cost occurs at moderate sequence.

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International Conference on Science &
Technology: Application in Industry
& Education (2006)

DEVELOPMENT OF DYNAMIC GANTT CHART FROM THE PRODUCTION SCHEDULING PERSPECTIVE

Ahmad Shamsul Osman[1], Shahrul Kamaruddin[2], Rosnah Idrus[1] and Zalinda Othman[3]

[1]School of Computer Sciences
Universiti Sains Malaysia
11800 Pulau Pinang
Malaysia

[2]School of Mechanical Engineering
Universiti Sains Malaysia
Engineering Campus
14300 Nibong Tebal.
Pulau Pinang, Malaysia.

[3]Department of Industrial Engineering
Faculty of Science and Technology
Universiti Kebangsaan Malaysia
43600 Bangi
Selangor, Malaysia

sham85_steady@yahoo.com, meshah@eng.usm.my, rosnah@cs.usm.my,
zalinda@ftsm.ukm.my

ABSTRACT

Gantt chart is a horizontal bar chart that graphically displays the time relationships between the different tasks in a project. The Gantt chart is used to display variety of tasks that are involved for particular equipment for a certain timeline. In relation to production scheduling, it is more of a display chart to show the work that needs to be carried out in a particular time period. It is used to clearly illustrate the tasks, jobs or processes and the machines or equipments that are used in completing the production. If there is interruption or change occurs on the shop floor, a new Gantt chart needs to be generated, which results in more time is spent on producing a new Gantt chart rather than in solving the problems itself. Therefore, there is a need to have a dynamic Gantt chart where changes can be made on the Gantt chart immediately to incorporate any changes. In this paper, the development of a dynamic Gantt chart is clearly discussed. It starts by giving a brief introduction of Gantt chart and how it is used in production scheduling followed by the development process where object-oriented design approach (OOD) is used as a modeling tool to capture the stages of the process and also the relationship of the objects in the systems. Then, a brief introduction to the algorithms developed for the drag-and-drop routine for the dynamic Gantt chart is discussed. The complete dynamic Gantt chart developed will be shown and discussed at the end of the paper.

Introduction

The static Gantt-chart contains planned dates for preventive maintenance or eventually planned maintenance. This is converted to a dynamic Gantt-chart to deal with situations involving on-line analysis for real-time maintenance signatures providing predictive functions as well as managing machines or equipment breakdowns. This is in addition to the planned preventive maintenance. Thus, the work presents a proposed software design for a complete Computerised Maintenance and Scheduling Management System (CMSMS). The system considers the integration of maintenance and the other manufacturing activities. Meanwhile, the related interfaces are also defined. The output of the system is a daily maintenance work plan, listed on a display for the maintenance team, so that they can perform the required every day maintenance operations more efficiently.

Gantt chart was created by Henry L. Gantt, an American engineer, in 1917. He developed the first Gantt chart for the planning of ship building during the First World War. The chart proved to be such a powerful analytical instrument that it had not undergone any changes for almost 100 years. It was only in the 1990s that link lines between tasks were added to the Gantt chart. Although now it is considered as a common charting technique, Gantt charts were considered quite revolutionary at the time they were first introduced. In recognition of Henry Gantt's contributions, the Henry Laurence Gantt medal is awarded for distinguished achievement in management and service to the community.

A Gantt chart is constructed with a horizontal axis representing the total time span of the project, broken down into timely increments (for example, days, weeks, or months) and a vertical axis representing the tasks that make up the particular project. Horizontal bars of varying lengths represent the sequences, timing, and time span for each task. A vertical line is used to represent the report date. In relation to production scheduling, Gantt chart is used in the form of a display chart to show the work that need to be carried out in a particular time period. A Gantt chart provides a graphical illustration of a schedule that helps to plan, coordinate, and track specific tasks in a project. In a Gantt chart, each task takes up one row. Dates run along the top in increments of days, weeks or months, depending on the total length of the project. The expected time for each task is represented by a horizontal bar whose left end marks the expected beginning of the task and whose right end marks the expected completion date. The tasks may run sequentially, in parallel or overlapping.

As the project progresses, the chart is updated by filling in the bars to a length proportional to the fraction of work that has been accomplished on the task. This way, one can get a quick reading of project progress by drawing a vertical line through the chart at the current date. Completed tasks lie to the left of the line and are completely filled in. Current tasks cross the line and are behind schedule if their filled-in section is to the left of the line and ahead of schedule if the filled-in section stops to the right of the line. Future tasks lie completely to the right of the line. From the explanation above, we can conclude that the best method to display a chart that clearly illustrates the tasks, jobs or processes and the machines or equipments that are used in completing the production scheduling is the Gantt chart.

The Advantages of Using Dynamic Gantt Chart Approach

Gantt Charts are useful tools for analyzing and planning a complex production scheduling. They:

- Help you to plan out the tasks that need to be completed.
- Give you a basis for scheduling when these tasks will be carried out.
- Allow you to plan the allocation of resources needed to complete the project.
- Help you to work out the critical path for a project where you must complete it by a particular date.

In essence, one single chart may show the whole production phase from the beginning to the end.

In production scheduling, the Gantt chart is generated from the schedule that is produced by the Computerised Maintenance and Scheduling Management System. The schedule is generated based on a particular algorithm, for example Genetic Algorithm (GA), to make sure that the schedule is fully optimized. The schedule will provide useful information such as equipment being used, tasks that are involved, dates, process times and tasks assigned to specific equipment. In the Gantt chart display, each task is differentiated by ID number and each ID number have its own color which means that different tasks can be easily identified visually. The equipments that are used will be sorted in vertical axis according to their name or ID number. For the horizontal axis, the scale of time will be set for example hour, days, week or month according to the total process time. An algorithm later needs to be created to place a task that needs to run for a particular equipment according to its start time and finish time. This algorithm will place the task via coordinate method. The coordinate will be generated by the system for each task using horizontal axis as X and vertical axis as Y. After each assignment of coordinate to task, there will be increment and decrement in the value of X and Y to make sure that the same coordinate will not be generated again. The task's process time will be converted into length in the Gantt chart. A scale will be set according to the total process time using an equation to make sure that the chart is in the allowed area of the display screen.

Now in modern technology, the evolution in the production scheme also affects the production scheduling process. All decisions and results must be accurate and at the same time, the time consumed in producing results needs to be as fast as possible. For example, if there is interruption or change occurs on the shop floor, a new Gantt chart needs to be generated. as a result, more time is spent on producing a new Gantt chart rather than in solving the problems itself. In order to produce another Gantt chart, the entire charting process need to be initiated again from beginning in order to include the change that is taking place. Therefore, there is a need to have a dynamic Gantt chart where changes can be made on the Gantt chart itself immediately to incorporate the changes.

Dynamic Gantt-chart Implementation

The previous section explains how a complete Gantt chart is generated from the production schedule. However, the Gantt chart generated initially is a static Gantt chart. What is needed now is the dynamic Gantt chart. This means that we need to add some extra features in the previous method to develop a dynamic Gantt chart. To make sure we can drag-and-drop tasks in Gantt chart, we need to make it as an object. For this, we need to use object oriented design approach (OOD) as a modeling tools to capture the stages of the process and also the relationship of the objects in the system. In this case, the task will be known as an object not only as a display property. Since in C# (the .net programming language used in CMSMS) there are controls and handler functions to control mouse movement, it is much easier to accomplish the drag-and-drop action. We only need to validate control that can handles the drag-and-drop function. The control from which we drag the item is called a *drag-drop source* and the control where we finally drop the dragged item is called the *drag-drop target*.

However, the first thing that needs to be done is to make sure that the Gantt chart area itself is a drop target. The controls have a property called *AllowDrop* which we need to set to true to enable the function. For drag-and-drop, there are four handlers to be used which are the *DragEnter, DragOver, DragDrop and DragLeave*. *DragEnter* occurs when the mouse pointer has dragged something and *DragLeave* occurs if it has dragged out of the control's client area without dropping the item. *DragOver* occurs after the *DragEnter* event and we need to signal our readiness to accept the dropped item. *DragDrop* occurs if the mouse is released on top of our control's client area. *DragOver* function is to capture and store the current coordinate X and Y properties of the *DragEventArgs* in the screen coordinates while the object is being dragged by the mouse to a new location and new coordinates. When the mouse is released the current coordinate will be assigned to the object. For *DragLeave* handler, we need to hide any visual cues that are currently being displayed when the mouse leaves our application. In *DragDrop* handler, we want to verify that the data being dropped is valid. This is to make sure that the object that is being dragged and dropped occurs in allowed area. *DragEnter* is to signal the *DragOver* that the mouse is now clicked by the user. Lastly, we need to add a handler for the *MouseDown* event for the Gantt chart. A MouseDown event occurs when you click the mouse anywhere within the Gantt chart to signal the *DragEnter* that an object is going be dragged. Figure 1 below is a screen capture of the Gantt chart from the CMSMS.

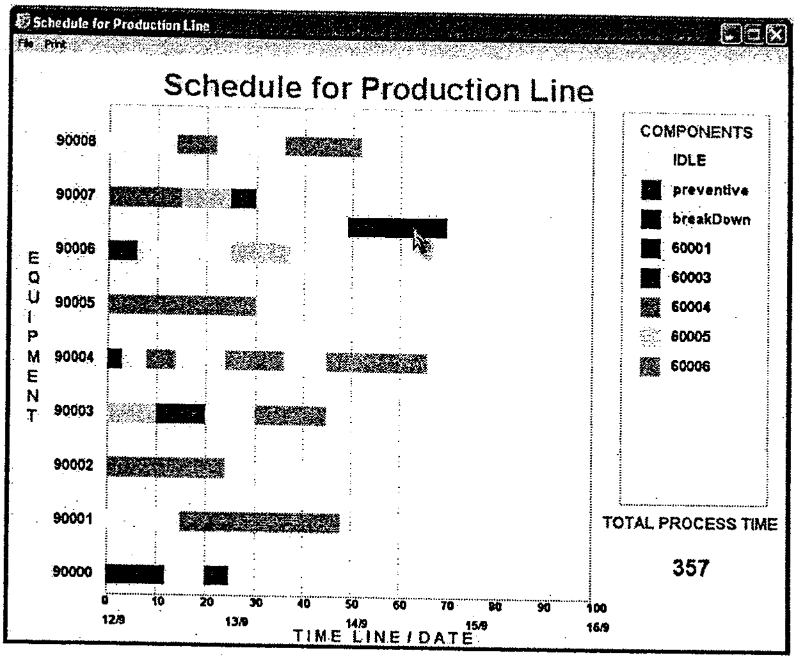

Figure 1: Example of Gantt-chart

Conclusion

As a conclusion, dynamic Gantt chart is very important nowadays for companies or organizations dealing with production scheduling. By applying this approach in production scheduling it can display the whole production phases from the beginning to the end in a very structured way and easily understood dynamic display. The dynamic Gantt-chart can be generated by the CMSMS and can be customized by users to deal with any breakdown conditions. This is the most important part in production scheduling i.e. to enhance the result of the schedule or reschedule due to machine breakdowns or failures for better production management. The constraints in static Gantt-chart can be overcome by using dynamic Gantt-chart.

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International Conference on Science &
Technology: Application in Industry
& Education (2006)

APPLICATION OF ARTIFICIAL INTELLIGENCE (AI) IN LAYOUT DESIGN AND PLANNING

Soh Chee Hong, Shahrul Kamaruddin

School of Mechanical Engineering
Engineering Campus
Universiti Sains Malaysia
14300 Nibong Tebal
Pulau Pinang
Malaysia

vincent_sohcheehong@yahoo.com, meshah@eng.usm.my

Abstract

We are now living in the era of the knowledge and intelligence revolution. Thus, the application of Artificial Intelligence (AI) has becomes important in a manufacturing industry to enhance and optimize the performance of their production system. Artificial Intelligence is the attempts to make machines or even technology do things which, if done by human, would be said to require intelligence. Layout design and planning are concerned about what is the suitable location of new or existent machine. Usually, research under this theme is focus on the improvement of productivity performance in terms of minimizing the overall production time, utilizing the existing space effectively, maintaining the flexibility of arrangement and operation. Application of AI in layout design and planning can develop a better understanding of the type and form of information which must be provided to improve accuracy, timeliness, and effectiveness of the manufacturing industries. Therefore, this paper will explore the contribution of AI in the layout design and planning in terms of improvement and optimization of the production system.

Introduction

Artificial Intelligence (AI) is one of the newest sciences. Basically, AI is a branch of computer science that addressed problems requiring human-like reasoning and intelligence, rather than machine-type processing. AI tries to bridge and minimise the gap between humans and machines by giving the machines some aspects of human capabilities (Herrod & Papas, 1985).

Layout is one of the key decisions that determine the long-run efficiency of operations, especially in a manufacturing operation (Heizer and Barry, 1996). It concerned about how to achieve placement of different resources to different locations within an area, as that the total cost of interactions is minimal. Layout design and planning process is a multi step process involving a host of implementation decisions. Basically, the objective of designing a layout is to improve utilisation of the resources such as machine, material handling and labour. It also helps to reduce inventory, WIP and setup time. Other than that, a well designed layout is able to maximize productivity, improve the flow of material, eliminate all unnecessary steps or waste, increase quality, and recover shop floor space.

The ability and characteristics of AI will be able to ease companies and researchers to design a high efficiency and effective layout. The success application of AI in layout design and planning will increase the profit of the company, and also improve the production performances. This paper will discuss the concept of AI, layout design and planning, and the application of AI in layout design and planning.

Artificial Intelligence

As mentioned previously, artificial Intelligence (AI) is a part of computer science concerned with systems that exhibit some characteristics usually associated with intelligence in human behavior (such as learning, reasoning, problem solving and the understanding of language). The goal of AI is to simulate human behaviours on the computer (Russell and Norvig, 1995). AI use computers in ways that are markedly differently from those of conventional data processing. All computers deal with symbols, but traditional symbols usually represent mathematical equations and numbers. By contrast, AI handles symbols that can represent almost anything - a concept, a person, and a process (Herrod and Papas, 1985). Generally, AI encompasses various methods which are shown in Figure 1. Referring to Figure 1, all the methods listed have been used widely in various manufacturing area such as manufacturing planning, scheduling, production control, design, equipment programming, and inspection instruction (David Liu, 1985). Some of the methods listed will be further discussed.

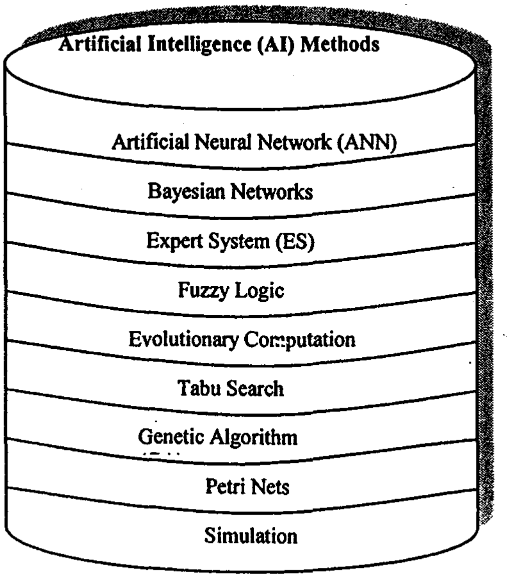

Figure 1 Various methods of Artificial Intelligence

Expert system (ES) is a type of AI that could be able to make decisions or solves problems in many fields, including finance, medicine, manufacturing and also engineering (Russell and Norvig, 1995). In making decisions or solves problems it combines the factual knowledge and reasoning ability of an expert that is programmed either using the expert shell or conventional programming. ES consist of two separate but related components; there are knowledge base and an inference engine. The knowledge base provides specific facts and rules about the subject, however the inference engine provides the reasoning ability that enables the expert system to form conclusions.

Simulation is a method by which models of alternative manufacturing scenarios may be developed and tested (Hurrion, 1986). The cost of changing and developing new manufacturing facilities is high so it has become essential to test out alternative manufacturing possibilities before implementation is carried out. Design and analysis, scheduling (particularly in automated systems), and real-time on-line control are the main three reasons for adopting simulation.

Artificial Neural Network (ANN) is an interconnected group of artificial neurons that uses a mathematical model or computational model for information processing. In most cases ANN is an adaptive system that changes its structure based on external or internal information that flows through the network. The utility of ANN models lies in the fact that they can be used to infer a function from observations. This is particularly useful in applications where the complexity of the data or task that makes the design of such function by hand impractical (Russell and Norvig, 1995).

Genetic Algorithm (GA) is a search technique used in computing to find true or approximate solutions for an optimisations and search problems. It is categorised as global search heuristics. GA is a particular class of evolutionary algorithms that use techniques inspired by evolutionary biology such as inheritance, mutation, selection, and crossover (also called recombination). It is implemented as a computer simulation in which a population of abstract representations (called chromosomes or the genotype) of candidate solutions (called individuals, creatures, or phenotypes) to an optimization problem evolves toward better solutions (Russell and Norvig, 1995).

Another method of AI is Tabu search. Tabu search is a powerful optimisation procedure that has been successfully applied for solving various combinatorial optimisation problems, including the traveling salesman problem, graph colouring problem, layout design and scheduling problem. It is simple to apply, implement, and easy to incorporate in the problem-specific constraints. Sometimes, it may also act as a control mechanism in monitoring and directing the progress of other optimisation routines (He and Kusiak, 1997).

Fuzzy logic is another one of the common and popular technique which has been used widely in AI field. It is derived from fuzzy set theory dealing with reasoning that is approximate rather than precisely deduced from classical predicate logic. It can be thought of as the application side of fuzzy set theory dealing with well thought out real world expert values for a complex problem (Russell and Norvig, 1995).

Petri net (also known as a place/transition net or P/T net) is one of several mathematical representations of discrete distributed systems. As a modeling language, it graphically depicts the structure of a distributed system as a directed bipartite graph with annotations. As such, a Petri net has place nodes, transition nodes, and directed arcs connecting places with transitions (Zha *et al.*, 2001).

Layout Design and Planning

Layout design and planning is concerned with the best placement of machines (in production settings), offices and desks (in office settings), or service centers (in settings such as hospitals or department stores). An effective layout facilitates will flow materials, people, and information within and between areas efficiently and effectively (Heizer and Render, 1996). A good performance layout requires some major criteria, such as the material handling equipment, capacity and space requirements, environment and aesthetics, flows of information and cost of moving between various work areas. The basic types of layouts in manufacturing industry are illustrated in Figure 2.

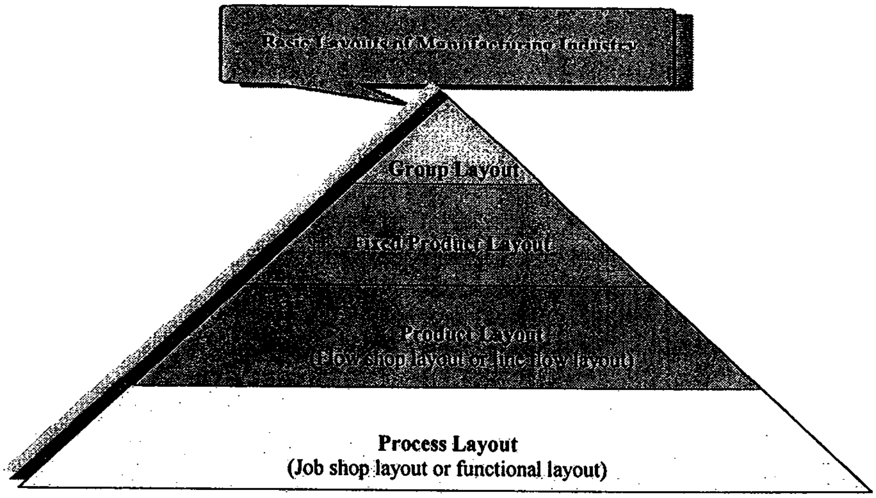

Figure 2 Types of layouts in manufacturing industry

The main objectives of layout design and planning is to provide smooth flow of works, materials and information through the manufacturing system. Layout design and planning is considered as an important issue in designing any manufacturing system. It is due to a large amount of investment involves. If any errors that occurs once the manufacturing system is implemented it will be costing a lot of monies to the company and affect the system efficiency.

Another objective of layout design and planning which is stated by Gero and Kazakov (2006) is to provide an arrangement of facilities that have maximum utilisation to achieve the desire goal of productivity and profitability. Other than that, Heizer and Render (2006) have stated that an effective facility layout design is able to reduce the manufacturing lead time and increase the throughput, hence increase the overall productivity and efficiency of the manufacturing system.

Artificial Intelligence in Layout Design and Planning

There are many researches have been carried out by academician and industries relating to application of AI in layout design and planning. Basically, they are using AI in many activities, such as designing and redesigning a layout, optimisation of layout, layout planning, problem prediction and problem identification which are shown in Figure 3. Some of the researches carried out will be discussed further in the following section.

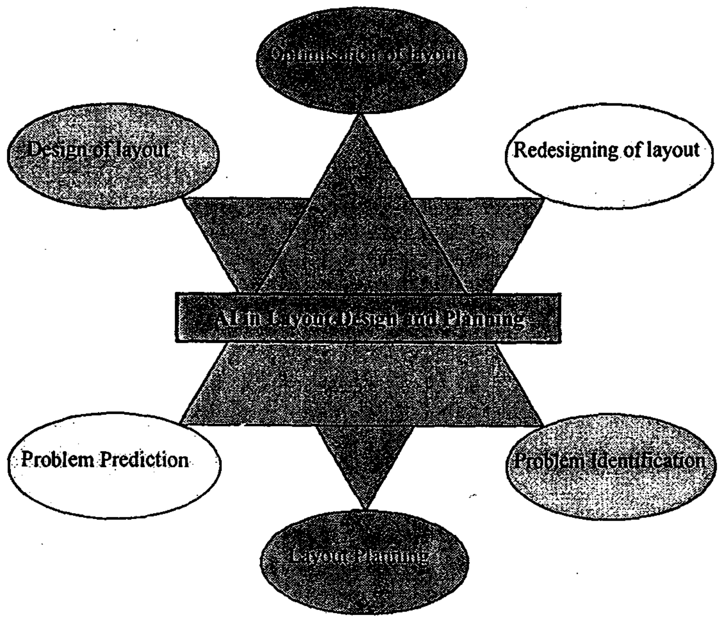

Figure 3 Activities of AI in Layout Design and Planning

Layout Design and Redesigning

Mendes *et al.* (2005) used Arena® Simulation Software to create an assembly model line for a PC camera. This software allows the modeler to fit a statistical distribution from the raw material, which can be integrated directly into the models. The created layout model allowed the modeler to better understand the actual and real assembly system operation. It also helps to validate all the assumptions used to build it and to gain the confidence of the decision makers regarding the methodology used.

Fjeld *et al.* (1998) introduced a simulation based technique to design a plant layout, called BUILD-IT. It is a planning tool based on intuitive computer vision technology, supporting complex planning and configuration tasks. A group of people will be seated around a table they move virtual objects with a real brick as an interaction handler. By using this method, the object manipulation and image display may take place within the very similar working area. Then, the new aspects of interaction and direct response were added to the computer-based planning process. A perspective view of the situation is projected on a vertical screen, together with the image displayed on the table. This system allows users to all kinds of access to state-of-the-art computing and visualisation. The system offers a new way of interaction, facilitating the team-based evaluation of alternative layouts. A simulation package called SIMPLE++ is integrated in the software. Hence, each alternative can be simulated and displayed using the visualisation capabilities of BUILD-IT.

Jo and Gero (2006) used GA in layout design. They introduced schema concept as the representation of design knowledge in the model. According to the authors, there are two kinds of design schemas: the design rule schema and the design gene schema. The design rule schema is used in the design formulation, whereas the design gene schema is used in the transformation of the design knowledge to the knowledge manipulable by the genetic search engine. With the existent advantages of genetic evolutionary design process, and based on the results obtained after the implementation, it showed that the coupling of an evolutionary search technique with a design process can produce a very good result, especially for large-scale problem which is at present computationally difficult.

An improved GA was proposed by Lee *et al.* (2003) to derive solutions for facility layouts that have inner walls and passages. The proposed algorithm models the layout of the facilities using the gene structures. Comparative testing shows that the proposed algorithm performs better than other existing algorithms for the optimal facility layout design. In addition to that, Zha *et al.* (2001) proposed a concurrent intelligent approach and framework for designing the robotic flexible assembly systems. The principle of the proposed approach is based on the knowledge of Petri net formalisms. The authors incorporated Petri nets with more general problem-solving strategies in AI using knowledge-based system. The results obtained by the authors shown that the proposed knowledge Petri net modeling is applicable and suitable for design, simulation, analysis, evaluation, and even the layout optimisation of the flexible assembly system in an integrated intelligent environment. The integration of assembly design and planning process can help reduce the development time of the assembly systems effectively.

A new object oriented approach called VisFactory was introduced by Sly (1998) which allowed users to create 2D / 3D models of their manufacturing system with less time and effort than it would normally take to create the current 2D drawings. VisFactory adds new object classes to AutoCAD that allowed for the drop-and-drag creation and editing of common manufacturing system geometry primitives. VisFactory primitives include items such as racks, cranes, conveyors, cabinets, workbenches, handrails, guardrails, fencing and mezzanines. These objects are used to create faster, highly accurate and intelligent 3D manufacturing system models that include logical equipment connections and data significantly beyond anything available within other current technologies.

Problem Identification and Prediction

Other than using AI in designing the plant layout many researchers used AI to identify and predict the problems that will be occurred in layout planning. Hasgül and Büyüksünetçi (2005) used Arena® Simulation Software to identify the bottlenecks of a new mixed model production line in a refrigerator company. They also evaluated the vacuum station and an AGV performance, cycle times and production performance by using the simulation software. In relation to that Taj *et al.* (1998) used WITNESS® simulation software to investigate the unbalanced cycle time and poor machine utilisation in a plant. This resulted in reduction of machine changeover times and increase throughput time. Smartt and Gill (1997) also used WITNESS® to identify the bottleneck, reduce distance travel by robot and increase percentage of machine busy time in a new designed robot cell for a flow shop layout. Otamendi (2005) On the other hand, used WITNESS to identify the problems in the ship building industry. He showed the advantages of using the simulation software in increasing the interaction of different knowledge groups in solving the problems.

Layout Optimisation

Optimisation plays an important role in layout design and planning. For example, Chao *et al.* (1997) developed an intelligent system to assist the layout designer in producing associativity data as input to an automated layout generation tool. The approach that the authors adopt combines various techniques based on expert systems, object-based data structures and cluster analysis. The manual input for the associativity data had been eliminated by the system. The object data structure is able to assure data consistency. The expert system provides guidance for the subjective part of the layout design. This results in automation of associativity data generation, an improved user interface, and consistency and accuracy of data. The expert system also provides a solution to ambiguous requests (e.g. high safety, low cost) from users regarding the selection of equipment. It is also able to select appropriate equipment by referring to the specification implicit in the Process Flow Diagram. The system allows users to spend less effort when producing associativity data. It alleviates the problems of combining subjective and objective factors by providing guidance to layout designers in generating such data.

GA is one of the AI methods which are suitable to be used as an optimisation tool in the layout planning and design. Gero and Kazakov (2006) studied the application of genetic engineering based extension from the genetic algorithms to the layout planning problem. They concluded that gene evolution which takes place when an algorithm of this type were running and demonstrated that in many cases it effectively leads to the partial decomposition of the layout problem by grouping some activities together and optimally placing these groups during the first stage of the computation.

In another work, Konak *et al.* (2005) introduced a mixed-integer programming formulation to identify the problem of a plant layout and find out the optimal solutions for the block layout problem with unequal departmental areas arranged in flexible bays. Flexible bay structure (FBS) is a continuous layout representation allowing the departments to be located only in parallel bays with varying widths. The authours stated that the bay boundaries form the basis of an aisle structure that facilitates the user transferring the block design into an actual facility design. In addition, many manufacturing facility designs follow an implicit bay structure. The FBS representation has been used as a design scheme in several heuristic approaches to the FLP. Facility layout software such as BLOCKPLAN and SPIRAL also generate layouts based on the FBS.

He and Kusiak (1997) presented the approach of the heuristic algorithm to optimize the layout design and planning based on the Tabu search. This algorithm considers concurrent partition of assembly operations and scheduling of products to minimize the total balancing cost of the modular product assembly system.

Nearchou (2005) suggested a modern meta-heuristic method from the field of evolutionary computation called Differential Evolution Algorithm (DEA) to optimize the layout. The performance of the DEA is measured through multiple characteristic experiments and compared to that of other known meta-heuristics such as genetic algorithms and simulated annealing. The experimental comparisons over a large set of randomly generated test problems show that the proposed DEA is superior to previous existing meta-heuristics approaches. Finally, the authors concluded that hybridizing the DEA with fuzzy systems is perhaps a promising area to start with and may result to a more robust optimization tool.

Conclusion

AI as an important new technology has been used widely in manufacturing field especially in layout design and planning. This is due to the characteristics of the AI which associated with the intelligence in human behaviour. This paper discussed the application of Artificial Intelligence (AI) in layout design and planning. The AI methods have been used to design and redesign a manufacturing plant layout, identify and predict the problem of layout, plan the layout and also optimize the layout. As a conclusion, the implementation of AI in layout design and planning activities is able to ease company personnel to solve the production problems relating to layout design and planning and provide an intelligent solution, in terms of minimize the unnecessary cost and time, optimize the performance of production and maximize the utility of the resources.

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International Conference on Science &
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Application of Simulation in Layout Design and Planning

Tan Yean Ching, Shahrul Kamaruddin

School of Mechanical Engineering
Engineering Campus
Universiti Sains Malaysia
14300 Nibong Tebal
Pulau Pinang
Malaysia

ABSTRACT

In modern world manufacturing economy environment today, the small and medium enterprise (SME) in contrast to big business, have a better reputation for innovation. For SME industry, the challenges those have to face included neglected infrastructure, limited access to credits and suffered from the lack of capital resources. In order for the SME to face the challenges as stated, one of the solutions is to redesign their production layout. Redesigning the production layout means that placing the right equipments, coupled with the right methods in the right place to permit the processing of a product unit in the most effective manner and by using the most suitable tool. One of the suitable tools for assisting the redesign process is simulation. Generally, simulation is a main part which involve in evaluating the effectiveness of the layouts that have been designed. Furthermore, by using simulation a computerized version of a process -- model will be created and it can be manipulated to do two things: analyze current operations to identify problem areas and test various ideas for improvement. This paper will give an overview on how simulation can be used in redesign the layout to achieve the improvement of manufacturing performance is discussed. It also show few example of work carried out by previous researchers related to layout design and improvement.

1. Introduction

Plant layout is the allocation of physical facilities such as workstation, machinery, and equipment in the shop floor to be used in production of raw materials to finish goods. Without compromising the intended operations flow's flexibility and smoothness, a desirable plant layout pursues optimum production rate with least material handling, time and cost. Nevertheless, in manufacturing operations, what is effective today may not be the ideal condition tomorrow (Vollmann et. al., 1997). As all manufacturing capabilities are influenced by the products it manufactured, plant layout needs to be revised periodically to keep abreast with changes in product variety, customer demands, manufacturing processes, machines, equipment and materials handling systems.

Often, assessing a plant layout takes into considerations of multiple mutually-constrained factors. In a typical factory, millions of products in different varieties and batch sizes are being produced each day. Each product variety despite highly similar in general, might require different processes, raw materials, labour skills and facilities. To promote facilities proximity so to avoid lengthy material handling is the first golden rule in plant layout design. However, longer process routing via material handling is necessary when a facility is needed by a handful of products. Some facilities are bounded to specific constraints, such as waste disposal exit, which complicates the designing. Certain criteria can only be evaluated subjectively; therefore few alternatives have to be generated for further reviews. To attempt each layout design alternative is an expensive endeavour. No doubt that any reposition of facilities, in reality, will cause disruption to the factory. If huge machineries or delicate processes are involved, specialised handling equipments and professional setup team have to be arranged. All these indirectly incur costly financial penalty to the company, e.g. installation cost, machine idling and losses in productivity. Also, it is noteworthy that an assessment will only be reliable after a period of time when the production system is reaching its stability. A poor layout design will naturally subject to more modifications, hence production idling and losses later. With so many factors to be considered, even the most experienced engineer sometimes fails to foreseen a particular flaw in design. In additions, modern manufacturing systems generally consist of distinct operations that might vary in performance over time. The non-linearly of manufacturing system can hardly be explained by any complex mathematical model. Therefore, with the ability to create artificial environment to perform experimentations, production simulation is a formidable tool for plant layout design. Through simulation, a real-life situation can be modelled on a computer. The variability in facilities performance can be examined where complexity is insufficient to be followed. With appropriate simulation, production behaviours with interactions among shop floor facilities and changes in the key parameters can be accurately predicted. As a result, how the system behaves can be studied (Heizer, 1996). Alternative plant layout can easily be compared and not least with the availability of clever functions that perform "what-if" evaluation to optimise a selected set of parameters.

The simulation technology has been around for a generation or more, with early developments mostly in the area of programming languages. In the last 10 to 15 years, simulation becomes prevalent due the advancement of computer technology, e.g. object-oriented programming, multi-agents system, virtual reality and 3D animation. Increasing number of simulation software is available: Witness, Arena, to name a few.

This paper emphasise on how simulation software simplifies and assists manufacturing company in plant layout design in particularly when trying to justify alternative layout performance. The paper is organised as follows: Section 2 discusses on the concept, the process of planning and developing plant layout design, followed by section 3, description on simulation develop and the types of simulation model. Section 4 describes the need to apply simulation technique in plant layout design.

2. Layout Design and Planning

Layout design and planning can be split into four basic steps, as shown in figure 1. The first step involves determining the floor space available for layout, including the nature and size of the area. The second step is to collect all information of the production intended on the plant layout. These include all the processes requirements and facilities parameters, environment and also safety concerns or constrains. Depending on the levels of details, the processing time, the machine breakdown rate and other aspects should also be duly considered. With all the information, a systematic plant layout planning can be commenced. The planning involves systematic layout development by prioritising the commonly used operation. More than one layout should be generated so that the most effective layout design can be decided in next development phase. Layout evaluation process begins with identifying company business objectives, production performance expectations or measures if the layout is to be used. Simulation come into place to evaluate each layout based on the measures. Post-analysis, e.g. 'What if analysis' will be conducted to optimise each individual layout.

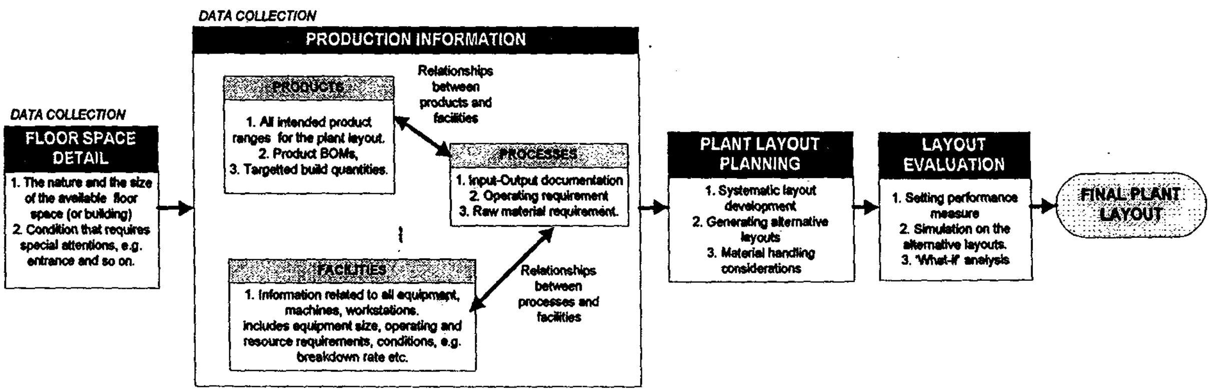

Figure 1 Research Steps for Layout Design Process

3. Simulation

Simulation models real life system on a computer to study how system works with the intention of predicting the system operational performance as well as its behaviour. The Oxford English Dictionary describes simulation as: *"The technique of imitating the behaviour of some situation or system (economic, mechanical, etc.) by means of an analogous model, situation, or apparatus, either to gain information more conveniently or to train personnel"*

A model is a representation of a system or process, which incorporates changes of states over time. In concept, a model's state is a (long) vector, that is, a list of values that are sufficient to define the complete state of the system at any point in time. In practice, a model's state is defined implicitly by the internal status of all the entities associated to the model. During execution, a computer program will run steps through time while updating the state and event variables of each entity. As shown in figure 3, there are several types of simulation, which are designed to handle different types of real-life system. Simulation modelling is divided into two major categories: Deterministic and stochastic modelling. Deterministic simulation assumes the initiate state of the system will always produce the same final stage when given the same inputs. Also known as monte carlo simulation (Doucet et al 2001), Stochastic simulation employs random numbers to model the chance or random events states where subsequent states will only partially influences the output of the model. That is, they contain some components that are modelled as a statistical distribution. This introduces random variation into a model, making it into a statistical or sampling experiment. More precisely, when one or more components are stochastic (for example, inter-arrival or service times), the model outputs are stochastic, necessitating some kind of statistical analysis to draw valid conclusions (Carson, 2005). Static or steady state simulation uses equations or formulas to model straightforward system, for example queuing theory. Dynamic simulation techniques emulate changes in a system in response to changing input variables. Continuous simulation modeling is used when continuous change predominates and its concern primarily is with the level of variables as well as the rate at which they are changing. In discrete event simulation, the operation of a system is represented as a chorological sequence of events where each event occurs at an instant in time and marks a change of state in the system (Robinson 2004). The technique of discrete event simulation therefore is system modelling method, where states change at discrete intervals of time (called event times). A discrete event system represented by either stochastic or deterministic models is capable of simulating machines or workstations and evaluating their performance measures based on manufacturing goals. The model therefore could be utilized for optimizing performance parameter as such model has the capability to predict systems performance based on interactions among system components and changes in the key parameters. Almost all discrete-event models are stochastic. Simulation Modelling in the form of discrete event simulation has evolved to become one of the most popular and cost-effective means of analysing complex systems. It is often used in industrial engineering, operations management and operational research to model many systems (commerce, health, defence, manufacturing, logistics, etc.) for example, the value-adding transformation processes in businesses, and optimize business performance.

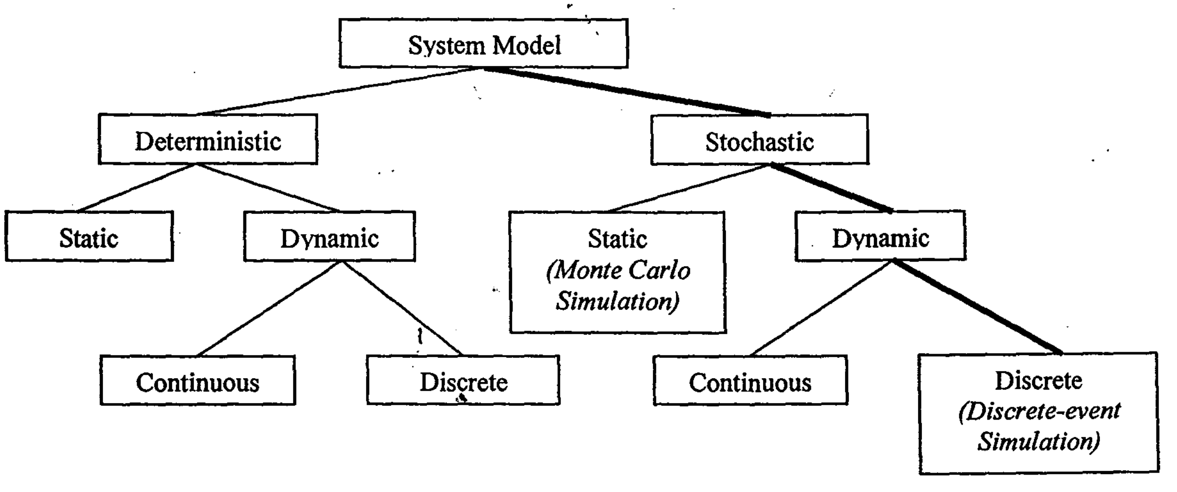

Figure 2 Model Taxonomy of Simulation

In general, production simulation software creates a virtual compound to represent the actual production layout. Production simulation software contains a library of elements that specifically model to reflect the behavioral characteristic of the actual object in the shop floor. Components to model include unit, stations, resources. An unit in the simulation model represents a process or subprocess while a station normally refers to a facility, workstation or machine. Resources are raw material, work-in-process, labour and other means necessary as inputs to operations. Some elements combine two elements together, e.g. create a material handling mechanism between two machines. The library is commonly displayed on computer screen as a tool palette where each different icon will be an element which can be drag and drop on a defined window space representing the layout. A new generation of simulation software enables a top-down modeling approach to capture complex production system that separate the model using multi-level process flows. As a result, a model in different hierarchical abstraction levels can be obtained. Once an element have been defined in the system, it can be replicated repeatedly to create a series of similar objects (for instance, machines with the same functions), thus saving time. These icons are later connected to represent the

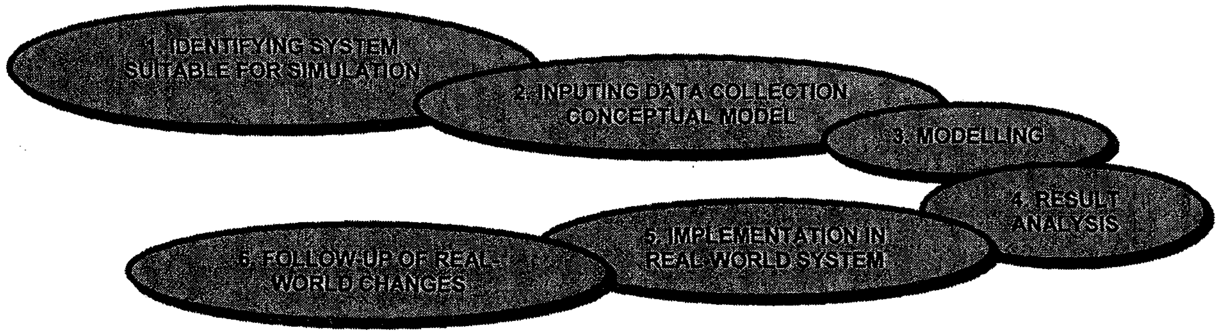

Figure 4 Process of Simulation in manufacturing system project

General guiding principles to be adopted when building a simulation are: simple to build, simple to modify, simple to understand and lastly simple to communicate its output. Simulation should not necessarily be treated as another technique for finding optimal solutions to problems. Quantitative analysis can be conducted once simulation model is developed by modifying certain key design parameters to observe the effect and the output result.

Several adaptations of simulation model can be found in real life industry. Chan (1995) employed simulation model to evaluate the performance of an automotive manufacturing system, as well as Cho *et al.* (1996) to identify parameters for system performance improvement at a Korean motor production facility. Bischak (1996) on the other hand, applied simulation to evaluate the performance of a textile-manufacturing module with mobile workers. A simulation model has also being used to verify that daily throughput requirements can be met at a new Mercedes-Benz assembly plant (Park *et al.*, 1998). Suri and Desiraju (1997) treated simulation as an interactive tool to validate analytical and predictive models for their flexible manufacturing system which consists of single material handling device. Simulation modelling, all in all, has provided a better structured, time and cost saving methods to deal with manufacturing challenges, particularly it is part of the intelligent planning and control system. The success of simulation applications in various industries clearly indicate that companies start to notice the benefits of simulation and its importance in finding solutions to ever changing scenarios.

5. Conclusions

An ideal plant layout should provide an optimum relationship among the output, floor area and manufacturing process. Its efficiency depends on how well the various machines; production facilities and amenities are located in a plant. Nevertheless, many experiments (in this instance, plant layout design) are expensive and time-consuming if is to be conducted on the real world (Pidd, 1998). To solve this, simulation model can be used as an experimental representation of the real manufacturing system/process layout, which clearly later acts as a significant analysis tool for implementing new manufacturing system. The application of simulation for solving manufacturing problems has been proven useful and effective for the ever-changing industry. By using simulation, the desirable plan can be studied in a short time-scale and allows improvements to be estimated on the existing shop floor without disruption to the actual production.

Today's manufacturing industry is facing problems that have been growing in size and complexity over the last several years. As a result, there is an immediate need for procedures or techniques in solving various problems encountered in today's manufacturing arena without extended shutdowns or expensive modifications (Clark 1996). Computer simulation is a powerful tool that allows experimentation with various manufacturing techniques and layouts without actual implementation. WITNESS simulation software for example, is widely using in process layout simulation for performance measuring method. With its unique strength not only the ability to identify and analyze manufacturing processes and propose changes as appropriate, but also to apply predictive technologies to quantify the benefit of the layout had been made. With a combination of modeling, analytical and optimization techniques, the simulation software will able to perform "what-if" experiments on manufacturing processes, instead of expending the time for running several of experiments to find the best solution. Furthermore, this simulation model could be utilized for optimizing performance parameters and is capable of predicting systems performance resulting from interactions among system components and changes in the key parameters.

The reminder of this paper is organized as follows. Section 2 discusses the layout design and planning. Section 3 provides description of simulation, as well as its component. Section 4 describes reasons of using simulation technique. Section 5 presents limitation of simulation.

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